EVALUATION PLAN TEMPLATE

Community-Level Greening Creates **Multiple Benefits**

May 2019

WILLAMETTE PARTNERSHIP

About this Template

Communities across the country are actively working to improve greenspace — planting and protecting trees, removing pavement to create pocket parks and gardens, installing green infrastructure as part of water, transportation, or housing development, and reclaiming land as neighborhood parks. Those communities are looking for ways to measure the benefits of their work to provide:

1. Estimates of anticipated health and environmental outcomes from proposed greening;
2. Another way to prioritize siting and types of greenspaces; and
3. A way to track and communicate progress over time.

This template is designed as a framework for community groups, cities, and/or coalitions working to increase urban greenspace to use to show the multiple benefits of their activities. It is meant as a starting point only. Any language can be adjusted to meet the needs of a particular community. This template evaluation design plan was developed by the Shift Health Accelerator team and Willamette Partnership. Any of it can be adjusted as needed. Shift Health Accelerator[1] is a program designed to simplify access to resources and tools for community-led efforts to change systems to advance health equity. This includes creating the environments, food systems, and economic inclusion that support healthy people.

The template was built using guidelines for equitable evaluation[2], the components needed to support outcomes-based investment for health and environment[3], and the experiences of measuring outcomes in Portland's Jade District (see Appendices). Our hope was that each of these building blocks will let communities measure and communicate their work in ways that advance justice and equity, expand their access to new funding streams, and continue to root work in the needs and values of their community.

The template was designed to measure community-level improvements from greening. There are tools to look at citywide health and environmental data (e.g., EnviroAtlas[4]), but there are limited tools to look at smaller scales that also incorporate local data. This template provides a framework for a finer scale evaluation. However, the science is still emerging. Some of the models used for Portland's Jade District can be difficult for communities to run without support. There is limited data that allows accurate predication of how planting 100 trees might change conditions 20 years from now for some factors (e.g., depression and physical activity). Many health variables are also shaped by social determinants, such as employment, race, transportation, and other systems (McGinnis, Williams-Russo, & Knickman, 2002), making it difficult to tease out any causal relationships between greening and health. Over the near term, this information is likely to get better, and this framework should be updated.

Blue boxes, like this one, provide background and instructions for completing the template. The words and sections highlighted in BLUE TEXT are likely places where you will want to add detail, insert, and change text.

[1] http://www.shifthealthaccelerator.org/
[2] https://www.equitableeval.org/resources
[3] https://home.treasury.gov/services/social-impact-partnerships/sippra-pay-for-results
[4] https://www.epa.gov/enviroatlas

Table of Contents

I. Overview of the Work, Evaluation Goals & Questions

We know more greenspace, tree canopy, and access to natural features improves environmental quality and human health (Frumkin, et al., 2017). Generally, more high-quality greenspace, that is closer to where people live/work/play, and is accessible for all people to enjoy can improve physical activity, mental health, social cohesion, air quality, and heat exposure. That greenspace can also reduce stormwater and flood volume, and improve stormwater runoff quality (e.g., removing heavy metals, sediments, and nutrients).

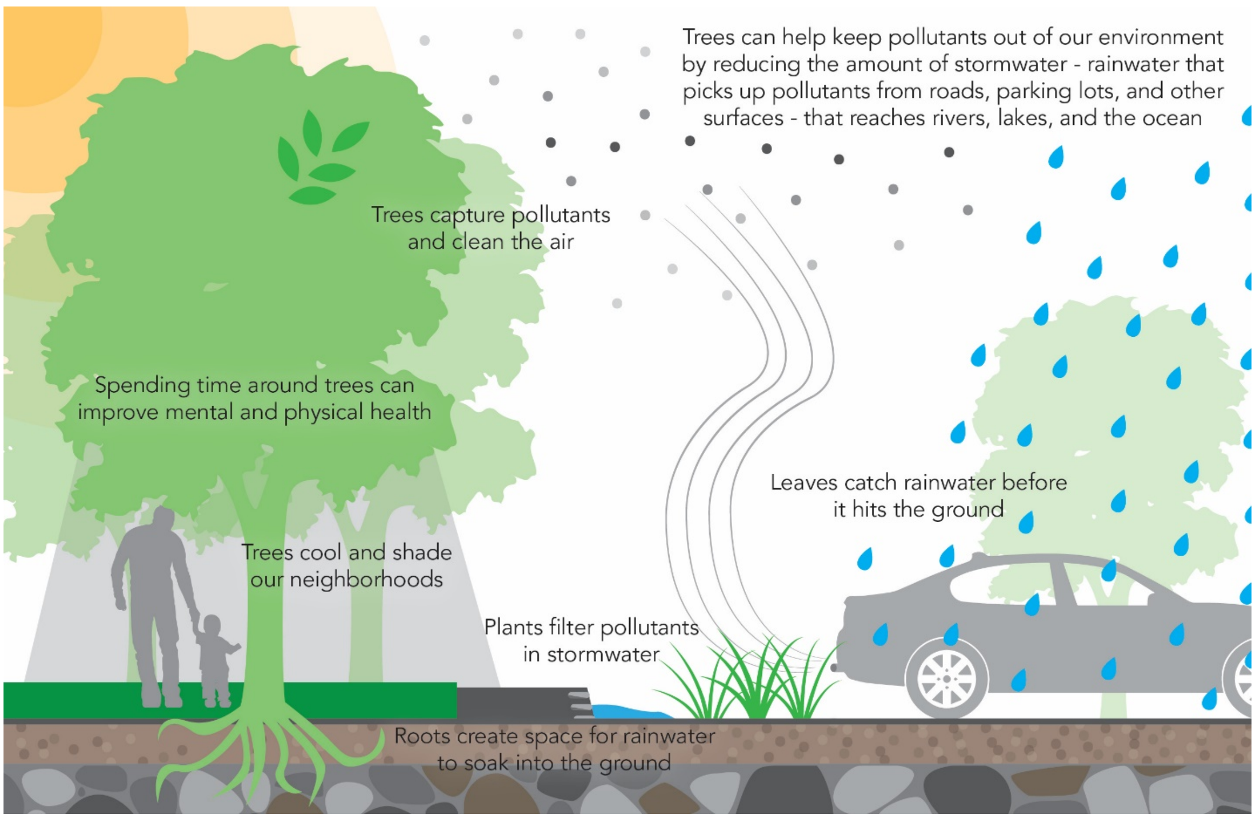

Figure 1: Urban trees and green spaces provide many health, air quality, and water quality benefits to our neighborhoods.

The PARTNERSHIP came together because of NEED to try and solve PROBLEM. The PARTNERSHIP will implement a range of activities to achieve a set of goals (see Table 1.1) — especially for POPULATION. USE THIS SECTION TO ADD ADDITIONAL DETAIL AND BACKGROUND ON WHY YOU CHOSE TO DO WHAT YOU ARE DOING, THE MAKEUP OF YOUR COMMUNITY, ETC.

Process Steps for Completing the Evaluation Design

Evaluation should be among the first things partners discuss in order to integrate evaluation with all other aspects of project planning. An early approach gives project partners time to ensure they have the resources to carry out the evaluation and to consider and prepare for how the chosen evaluation design might shape planning and operations.

Step 1. Identify how you will use the information and what outcomes you hope to achieve and measure

Step 2. Identify the measures for each of the outcomes & the scale of measurement (using multiple measures at the city, community, neighborhood, and city block levels allows you to tell stories about who exactly does or does not benefit from greening efforts)

Step 3. Select the methods and tools to gather information on those measures

Step 4. Collect data and set-up models

Step 5. Analyze results

Step 6. Package and communicate results

Table 1.1. Program Goals and Activities

Aim for SMART goals: Specific, Measurable, Assignable, Relevant, and Time-based

Goal	Timeline	Activities Description, documentation of, data collection instruments
1. Improve air quality		
Objective 1.1: Reduce NO2 by X%	By YEAR	Planting trees
Objective 1.2: Reduce PM 2.5 by Y%	Within X months	Planting trees
Objective 1.3: Reduce extreme heat	By YEAR	Planting trees
2. Improve water quality and quantity		
Objective 2.1: Reduce stormwater flow (cubic meters/sec) by X	By YEAR	Planting trees; Reducing impervious area; Increasing greenspace area; Installing green infrastructure
Objective 2.2: Reduce water pollutant loads [Total suspended solids, Biological oxygen demand, Chemical oxygen demand, Total phosphorous, Total nitrogen, Copper, Lead, Zinc (kh/hr)]	Within X months	Planting trees; Reducing impervious area; Increasing greenspace area; Installing green infrastructure
3. Improve human health		
Objective 3.1: Improve physical activity by X%	By YEAR	Community participation in planting; Planting trees; Reducing impervious area; Increasing greenspace area; Installing green infrastructure
Objective 3.2: Improve mental health (overall mental health, depression and anxiety, stress) by Y%	By YEAR	Community participation in planting; Planting trees; Reducing impervious area; Increasing greenspace area; Installing green infrastructure

Goal	Timeline	Activities Description, documentation of, data collection instruments
3. Improve human health		
Objective 3.3: Improve social cohesion by Z%	By YEAR	Community participation in planting; Planting trees; Reducing impervious area; Increasing greenspace area; Installing green infrastructure

The PARTNERSHIP will use evaluation to improve programs and community connections, demonstrate the outcomes of the work, and communicate with partners about how the program is working. The evaluation is designed to answer the questions listed in Table 1.2.

Table 1.2: Evaluation Questions

Purpose	Question	Audience for the answers
Program improvement	How are participants feeling about what's working and what could improve about the INTERVENTION? What is important to learn most given the resources available for evaluation?	Community providers; Partners
Outcome determination	What are the conditions before the greening work? What is the impact of INTERVENTION on OUTCOMES compared to a similar group who did not participate in the INTERVENTION?	Funders; Providers/Partners
Evaluation Design	What are the best possible methodologies for measuring success to reduce points of possible critique? Which design balances evaluation equity and establishing a strong base of evidence for program effectiveness	Funders/Providers (at a minimum, ideally community and partners too)
Communication to partners and external people	What were the benefits of the INTERVENTION? What were some of the unanticipated challenges of the INTERVENTION? What are the best formats for communicating findings, and who are the best messengers?	Community; Outside stakeholders Funders/ partners
Which data will help to tell this story – implications for monitoring, formal data sharing agreements, etc.?	In what ways are the community better off, or trending toward being better?	Providers/Partners/Community

Other Considerations for Evaluation Planning

Four core considerations should emerge in early evaluation planning. These considerations are interrelated, and partners may need to address them iteratively throughout their planning process:

1) **Review previous evaluation** – are we familiar with the evidence base/previous findings of the intervention?
    a. Is external validity a concern?
    b. If there is less existing evidence (i.e., this is a new initiative) is there greater incentive to choose a strong evaluation design to assess outcomes?
2) **Identify priority population** – what is the sample size of participants needed to detect an effect?
3) **Selection bias** – When using experimental and quasi-experimental design:
    a. Is there proper randomization of controlled trials?
    b. Is there an omitted variable bias (are we missing important factors/variables that might over- or under-estimate the effect of the intervention?)
4) **Defining the metrics to be tracked and analyzed**
    a. How much time is needed to demonstrate results?
    b. How much of the intervention do the participants need to receive to make a difference?
    c. Who is doing the measuring before and after the intervention?
    d. What kinds of training and inter-rater reliability checks will be employed?
    e. Will measures be executed using pencil and paper, tablets, or another mode?
    f. In quasi-experimental or non-experimental evaluations, how will a representative control group be identified and assessed?
    g. What kinds of data review and cleaning procedures need to be established?
    h. How will the evaluation team ensure the privacy and confidentiality of participants?

Process and impact evaluations both rely on accurate and complete data collection and analysis. If secondary data is to be used, it is critical to understand local data systems and the reliability of data in those systems a successful evaluation.

II. Proposed Logic Model & Summary of the Base of Evidence

Inputs	Activities	Process Outcomes	Initial Outcomes	Intermediate Outcomes	Long Term Outcomes
• **Staff from** PARTNER ORGANIZATIONS • **Volunteers** • **Materials for tree plantings, tree care, neighborhood cleanup, and other greening activities** • **Space for neighborhood meetings**	Program Planning • Build relationships • Develop and evaluation plan • Recruit volunteers Tree/ Greenspace Focused • Tree planting • Tree walks • Tree care • Community gardens • Backyard habitat • Pavement removal Community Focused • Neighborhood clean up • Canvassing • Meetings	• **Number of events organized** • **Number of attendees** • **Number of trees planted** • **Increased area of greenspace**	• **Increase community greenspace** • **Increase tree canopy** • **Neighborhood beautification** • **Community attachment** (Arnberger & Eder, 2012) (Maas, Dillen, Verheij, & Groenewegen, 2009) • **Physical activity** (Hillsdon, Panter, Foster, & Jones, 2006) (Coombes, Jones, & Hillsdon, 2010) • **Mental health** (van den Berg, Maas, Verheij, & Groenewegen, 2010) (Alcock, White, Wheeler, Fleming, & Depledge, 2014) (Astell-Burt, Mitchell, & Hartig, 2014) (Barton & Pretty, 2010) (Nutsford, Pearson, & Kingham, 2013)	**Improved roadside safety** (Wolf, 2010) • Stress reduction • Traffic calming • Reduced crashes **Pollution removal** • Air quality improvements (Nowak, Hirabayashi, Bodine, & Greenfield, 2014) (McPherson, Nowak, & Rowntree, 1994) • Water quality improvements (Center for Watershed Protection, 2018) **Reduced crime** (Troy, Grove, & O'Neil-Dunne, 2012) (Kuo & Sullivan, 2001) **Improved birth outcomes** (Donovan, Michael, Butry, Sullivan, & Chase, 2011)	• **Reduction in heart disease** (Donovan, Michael, Gatziolis, Prestemon, & Whitsel, 2015) • **Reduction in acute respiratory symptoms** (Nowak, Hirabayashi, Bodine, & Greenfield, 2014) • **Reduction in asthma** (Lovasi, Quinn, Neckerman, Perzanowski, & Rundle, 2008) (Lovasi, et al., 2013)

Key
Inputs: What are the resources needed for the program?
Activities: What activities will the program implement?
Process outcomes: What is produced?
Initial outcomes: Outcomes that occur within the first year of the program. For the most part, these outcomes will continue into intermediate and long-term outcomes.
Intermediate outcomes: Outcomes that occur 3-5 years after the start of the program. For the most part, these outcomes will continue into long-term outcomes.
Long-term outcomes: Outcomes that occur 5+ years after the start of the program. For the most part, these outcomes will continue into long-term outcomes.

2.1. Summary of the Evidence Base

INSERT RELEVANT EVIDENCE/LITERATURE REVIEW FROM GREEN INFRASTRUCTURE AND HEALTH GUIDE (Cochran, Henke, & Robison, 2018)[5].

III. Evaluation Design & Methods

The evaluation proposes to use EVALUATION DESIGN TYPE.

When choosing an evaluation design consider: 1) Is a more rigorous evaluation design feasible? 2) Does the design have anything to compare the outcomes measured against? 3) Is it important to understand program impact, or is it sufficient to quickly and clearly measure outcomes achieved? **Most community greening efforts are likely to use Pre-Post Comparisons.**

Evaluation Design Type	Suggested Language
Randomized Controlled Trial	A randomized controlled trial, which is a reflection of the program's effect by comparing performance to a randomized control group.
Quasi-Experimental Design	A quasi-experimental design, which creates a comparison group as identical to the treatment group as possible, in the absence of randomization. These designs attempt to minimize bias from competing explanations and use various statistical methods to approximate a randomized controlled trial's rigor.
Matched Comparison Group Design	A matched comparison group design, where one group participated in the INTERVENTION and a similar group did not.
Pre-Post Comparison	A pre-post comparison of OUTCOME LEVELS before the INTERVENTION and outcomes after the INTERVENTION for the same group of people.
Difference-in-Difference Design	A difference-in-difference design compares change in outcomes over time for the treatment group, and compares this with change in outcomes over time for the control group.
Non-Experimental Designs/Pre-Post Analysis	A pre-post analysis that does not include an untreated comparison or control group but instead focuses on the number of participants who experience targeted outcomes. Because these designs do not compare the outcomes of the people treated by the program with people who were not, and because they do not account for competing explanations, such as broader economic trends or changing neighborhood demographics, they may lead to conclusions that could be contradicted by a more sophisticated design.

[5] http://willamettepartnership.org/green-infrastructure-health-guide/

The study/intervention group the evaluation will look to is defined as INSERT DESCRIPTION OF STUDY GROUP (e.g., residents who live adjacent to new tree plantings - n = 120; or people who participated in tree planting events - n=50).

The comparison/control group the evaluation will look to is defined as INSERT DESCRIPTION OF COMPARISON GROUP (e.g., residents in similar neighborhoods without trees - n=240; or similar people who did NOT participate in tree planting - n=100).

3.1. Metrics & How They Will be Measured

The following measures and metrics will be used to determine to determine if outcomes have been achieved (see Table 3.2.1).

Why Look at Air, Heat, Water Quality and Quantity, and Health

Air pollution and heat are two measures of environmental quality that are well-known to have detrimental effects on human health. For this framework, we have currently developed an approach to modeling anticipated change in exposure to air pollutants (NO2) and extreme heat as a result of the greening efforts, particularly tree planting. NO2 is a byproduct of truck and auto combustion and often are tied to other airborne pollutants that are more difficult or expensive to measure (e.g., PM 2.5, heavy metals, benzene, etc.). Exposure to extreme heat is discussed with air quality because modeling the flows of air and how trees function is similar for each.

Urban areas can contribute to water quality issues when stormwater from precipitation events runs off or is directed from these areas to drainages and streams. The stormwater runoff from urban areas can mobilize pollutants from yards and open space areas (e.g., sediment, fertilizer, pathogens and bacteria from pet waste, and pesticides) as well as pavement and other impervious surfaces (e.g., chemical and petroleum product spills and deposition of air pollutants from mobile sources, such as motor vehicles). These pollutants can make their way into the environment and water bodies where they can affect fish and wildlife and cause detrimental human health affects (e.g., skin irritation, sickness, and contaminated drinking water). Greening projects are known to improve water quality of runoff from parking lots, roads, and other impermeable surfaces by capturing and filtering sediment, nutrients, and heavy metals. Trees are able to reduce the quantity of stormwater runoff through interception that occurs when precipitation is caught in the tree canopy and evaporates before reaching the ground. The tree canopy also serves to reduce the amount of force or energy that precipitation has when it hits the ground, resulting in less mobilization of sediment and other pollutants deposited on the ground. Tree roots are able to increase the precipitation that can infiltrate into the soil and that can be held there, instead of running off and carrying pollutants into receiving water bodies (Environmental Protection Agency, 2018).

Contact with nature — whether street trees, parks, or natural areas is known to improve a wide range of health factors (Frumkin, et al., 2017). Those health benefits range from improved mental health and physical activity to stronger social cohesion and reduced mortality (see Frumkin et al., 2017, Table 1 and Green Infrastructure and Health Guide Table 3). Although current research has found strong correlations between nature contact and health, the research relative to which kinds of nature, how much, how often, and how different people respond for health is still emerging. The research gap around the "dose-response" for nature makes it challenging to build predictive models linking increase in tree canopy or access to greenspace and health. The current version of this framework provides tools to evaluate the individual health benefits of people who have participated in a community tree planting event relative to mental health, physical activity, and social cohesion.

3.2. Analytical Methods

See more detailed descriptions of analytical methods in APPENDIX X.

Thinking Ahead About Analysis

For this template, we included descriptions of data collection and analytical methods used for Portland's Jade District in Appendices B through D. How data will be **analyzed** relative to the evaluation questions is important to determine up front with all partners. For this framework, we tested a combination of individual surveys, collection of spatial data, and use of predictive models. Some of these methods can be easily analyzed by community groups, but some of the predictive models needs skills in GIS and model runs that not all groups may have. It is important to have a conversation about how to tell a story about outcomes that uses quantitative data and qualitative data.

Table 3.2.1: Outcomes, Measures, and Metrics

Final Outcome	Intermediate Outcome/Activities	Measure	Data Source	Data Collection Approach
Improved air quality	Trees grew and survived	# of trees planted that survived for 5 years	City & community records of tree survival and growth	Visual inspections connected to spatial locations
	Trees planted	# trees planted in proximity to priority population	City & community group records of planting location and species; and/or projected planting locations (e.g., Branch Out PDX[6])	Spatial locations with species and soil attributes
	NO2 reduced	% reduction in NO2 exposure	Current and projected future tree canopy cover (e.g., local LiDAR data); impervious surfaces (e.g., local land use/land cover data); and PSU NO2 Model Analysis output from the study area	NO2 modelling & spatial analysis
	Economic value of improved health from less NO2 exposure	$ of reduced healthcare utilization from a % decrease in NO2 exposure	Pre and post NO2 concentrations (NO2 model output);	BenMAP[8] model runs to generate health incidence and values

[6] http://www.branchoutpdx.org/
[8] https://www.epa.gov/benmap

Final Outcome	Intermediate Outcome/Activities	Measure	Data Source	Data Collection Approach
			demographic data (PopGrid[7])	
	Heat reduced	Degrees of cooling during extreme heat by city block or household	Land cover, building heights, impervious surfaces, and current and projected tree canopy cover (e.g., local LiDAR and land use/land cover data); mature height of trees and projected growth rates (user defined); initial temperature and wind speed (e.g., Weather Underground[9])	ENVI-Met[10] model runs of the study area; Urban Heat Island (UHI) model runs for the study area
Water quality	Trees planted	# trees planted in proximity to priority population	City & community group records of planting location and species; and/or projected planting locations (e.g., Branch Out PDX)	Spatial locations with species and soil attributes
	New pervious area increased	Area of pavement or other impervious surface removed	City & community group records of impervious surface removed	Spatial locations with surface/soil attributes
	New green infrastructure facilities created	# and type of new green infrastructure facilities	City & community group records of new green infrastructure facilities	Spatial location and surface/soil attributes
	Stormwater volume reduced	Change in cubic meters/sec of stormwater flow	Land cover, impervious surfaces, and current and projected tree canopy cover (e.g., local LiDAR and land use/land cover	i-Tree Hydro model runs of study area

[7] https://www.popgrid.org/
[9] https://www.wunderground.com/
[10] https://www.envi-met.com/

Final Outcome	Intermediate Outcome/Activities	Measure	Data Source	Data Collection Approach
			data, i-Tree Hydro[11], i-Tree Canopy[12]); soil type (USDA Natural Resource Conservation Service); mature height of trees and projected growth rates (user defined); precipitation (e.g., Weather Underground[13]); stream flow (US Geologic Survey historic stream gauge data[14])	
	Pollutant loading reduced	Change in kg/hr of pollutant loading	Land cover, impervious surfaces, and current and projected tree canopy cover (e.g., local LiDAR and land use/land cover data, i-Tree Hydro, i-Tree Canopy); soil type (USDA Natural Resource Conservation Service); mature height of trees and projected growth rates (user defined); precipitation (e.g., Weather Underground[15]); stream flow (US Geologic Survey historic stream gauge data[16])	i-Tree Hydro model runs of study area

[11] https://www.itreetools.org/hydro/
[12] https://canopy.itreetools.org
[13] https://www.wunderground.com/
[14] https://waterdata.usgs.gov/nwis/uv/?referred_module=sw
[15] https://www.wunderground.com/
[16] https://waterdata.usgs.gov/nwis/uv/?referred_module=sw

Final Outcome	Intermediate Outcome/Activities	Measure	Data Source	Data Collection Approach
Human Health	Community participation in tree planting	# of people participating in tree planting	City & community group records of who participated in greening	Event registration and survey
	Trees planted	# trees planted in proximity to priority population	City & community group records of planting location and species; and/or Projected planting locations (e.g., Branch Out PDX)	Spatial locations with species and soil attributes
	Greenspace created	Area of new greenspace within a 10 min walk of priority population	City & community group records of greening location, area, and amenities	Spatial locations with amenity attributes
	Improved physical activity		Community group-collected surveys	Individual survey of self-reported health
	Improved overall mental health		Community group-collected surveys	Individual survey of self-reported health
	Improved depression and anxiety		Community group-collected surveys	Individual survey of self-reported health
	Improved stress		Community group-collected surveys	Individual survey of self-reported health
	Improved social cohesion		Community group-collected surveys	Individual survey of self-reported health

3.3. Subject Recruitment

The priority population for the greening work was identified as INSERT DESCRIPTION because INSERT REASONS (E.G., HEALTH AND INCOME DISPARITIES, LACK OF ACCESS TO GREENSPACE, ENVIRONMENTAL RISK, ETC.).

IV. Suitability of the Project/Actions/Work for the Proposed Evaluation

INSERT ADDITIONAL DETAIL ON THE "EVALUABILITY" OF THE ACTIVITIES. THIS MAY NOT BE NECESSARY FOR MANY EVALUATION DESIGNS, BUT MAY BE FOR FUNDERS WHO REQUIRE A HIGHER LEVEL OF EVIDENCE.

V. Approach for Data Collection and Coordinating Partners

INSERT ADDITIONAL DETAIL ON HOW YOU WILL COLLECT DATA, WHO WILL DO IT, HOW YOU WILL PROTECT SENSITIVE INFORMATION, ETC. THIS MAY NOT BE NECESSARY FOR MANY EVALUATION DESIGNS, BUT MAY BE FOR FUNDERS WHO REQUIRE A HIGHER LEVEL OF EVIDENCE, OR EVALUATIONS THAT REQUIRE A NUMBER OF PEOPLE OR COLLECTION OF SENSITIVE INFORMATION THAT MIGHT REQUIRE INSTITUTIONAL REVIEW AND HUMAN SUBJECTS PROTECTIONS.

VI. Engaging Community, Protecting Independence, and Quality Assurance

6.1. Community Engagement Strategy

Applying Best Practices

Any element of community-led work, including evaluation, is often stronger with deep community engagement. The following elements are drawn from best practices from the Equitable Evaluation Initiative[17].

This evaluation is designed to support both formative evaluation (e.g., ongoing learning and program improvement) and summative evaluation (e.g., confirmation of outcomes). The approach recognizes the value of active community engagement AND the need for independent confirmation of outcomes tied to payments.

[17] http://www.equitableeval.org/

The evaluation has engaged community in:

- Determining the purpose, goals, and questions of the evaluation;
- Prioritizing the outcomes important to the community and the partners; and
- Creating an evaluation approach that provides relevant, transparent information on how work is or is not making a difference for people in the community.

The evaluation will engage community in:

- Reviewing the initial findings of the local evaluator;
- Collecting the data needed to determine outcomes;
- Providing stories, narrative, and other information important to understanding the context and meaning of the evaluation findings; and
- Deciding when to engage an independent evaluator to confirm outcomes.

6.2. Independent Evaluation

Independent Evaluation

Some funding sources may require an independent evaluation of outcomes, but not all. The language below is consistent with the Social Impact Partnerships to Pay for Results Act criteria from US Department of Treasury[18].

The partners recognize the value of independent confirmation of outcomes. For this evaluation, an independent evaluator is someone who:

- Is free from conflicts of interest as defined in APPENDIX X Conflict of Interest Policy — financial or otherwise has a stake in the outcome;
- Is qualified to review the data, process, and outcomes relative to both the subject matter and the process used; and – an independent evaluator's required credentials can include knowledge of the community, cultural humility, familiarity with equity evaluation frameworks, etc.; and
- Has been trained in avoiding conflicts of interest, maintaining independence, and working consistent with the program's values and processes.

6.3. Quality Assurance and Control Approach

INSERT ADDITIONAL DETAIL ON HOW YOU WILL ENSURE THE QUALITY OF DATA COLLECTED, THE ACCURACY OF ANALYSIS AND REPORTING, AND THE PROTECTION OF CONFIDENTIAL DATA.

[18] https://home.treasury.gov/services/social-impact-partnerships/sippra-pay-for-results

VII. Anticipated Challenges

There are several challenges anticipated for this evaluation and several strategies will be used to mitigate those challenges (see Table 7.1).

Table 7.1: Evaluation Challenges & Strategies to Mitigate Challenges

Challenge	Impact of Challenge	Mitigation Strategy
Participation in the intervention changes	Experimental validity	
External variables change	Hard to demonstrate causality	
In what ways are the community better off, or trending toward being better?		

VIII. Decision-making and Reporting

Several evaluation decisions need to be made along the way to determining outcomes (see Table 8.1).

Table 8.1: Decisions and Supporting Reports

Decision	Supporting Report	Who Decides
Are outcomes ready to evaluate?	Community provider progress reports	Community providers
Were outcomes achieved?	Local evaluator's Report of Initial Findings	Local evaluator
Should outcome payments be released?	Independent evaluator's Confirmation of Findings	Independent evaluator
Release of payments	Confirmation of Findings; Community Providers' Invoices	Partner Funders

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Appendix A: The Health, Air, and Water Benefits of Greening the Jade District

THE HEALTH, AIR, AND WATER BENEFITS OF GREENING THE JADE DISTRICT

Prepared for: Asian Pacific American Network of Oregon
Prepared by: Willamette Partnership
Last Updated: May 2019

Did you know your zip code determines more of your health than your genetic code? Where and how we live in and around the Jade District makes a difference in our community's health, environmental quality, and our ability to thrive. Studies of human vulnerability suggest that communities that are consistently exposed to air pollution and extreme heat encounter more health-related challenges than all other environmental factors combined.[1] When more people have access to trees, trails, parks, and other natural areas, there are measurable improvements in mental health, physical activity, social cohesion, air quality, water quality, and other social determinants of health. This report[2] summarizes some of the benefits the Jade District Greening efforts are generating now, and into the future.

Jade District Greening Goals

Increase greenspace
Improve traffic safety
Improve health

The Jade District is located on Portland's east side (Census Tracts 83.01, 16.02, and 6.01) where about 14,000 people live in a 2 square mile area bordered by the 205 freeway, 82nd Avenue, and other high volume transit corridors. The Jade District is one of the most ethnically and linguistically diverse zip codes in Oregon (53% residents of color), and there are active community leaders and community-based organizations. But residents face significant health challenges. For example, asthma rates ranged from 13.8-18.4% in this area, compared to 8.9% for all of Multnomah County, and on average, one in two Jade District residents using Medicaid visit the emergency room each year.

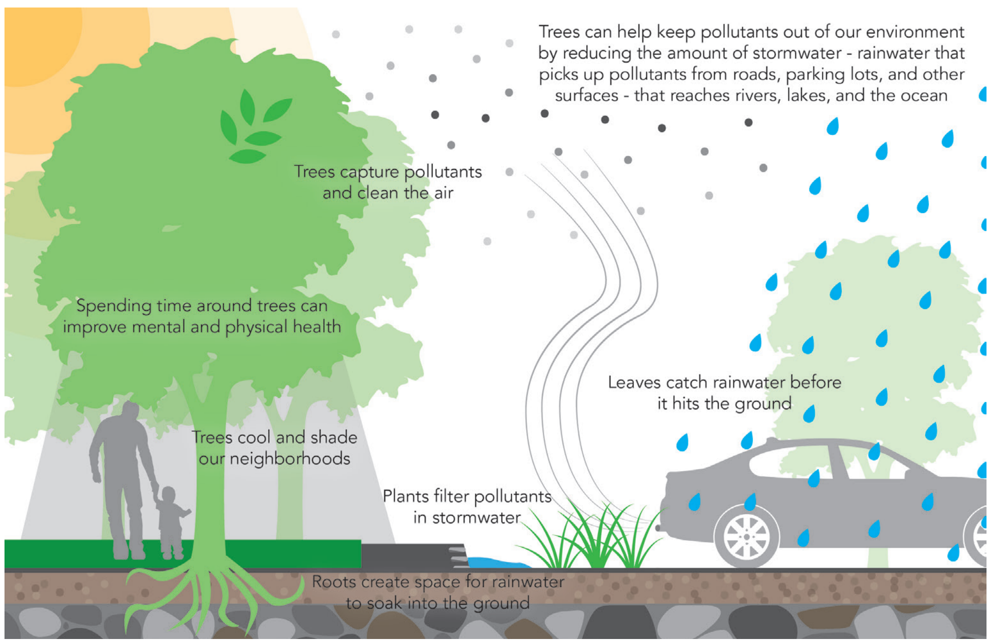
In 2016, a coalition of community, city, nonprofit, and other organizations launched the Jade District Greening effort to help address these challenges.

[1]Cutter, S. et al. (2003) "Social Vulnerability to Environmental Hazards." Social Science Quarterly, 84(2): 242-261.; Klinenberg, E. (2002). Heat wave: A social autopsy of disaster in Chicago. Chicago: University of Chicago Press.; Polsky et al., 2003. The Vulnerability Scoping Diagram (VSD). Global Environmental Change 12; 1211-1229.
[2]This Jade District greening benefits summary was created as part of a broader project to build a measurement framework and strategies for neighborhoods and communities to measure and articulate the health, water, and air benefits of their local greening efforts. More information on the measurement framework can be found at http://willamettepartnership.org/evaluating-greening-benefits; the data and models used to create this summary can be found in Appendices B-D of the framework.

Greening Benefits Summary

Between 2017 and 2019, Jade District greening partners planted 364 trees, created over a thousand square feet of new greenspaces, and interacted with over a thousand community members through volunteer and outreach events. The Asian Pacific American Network of Oregon (APANO) worked with Providence Center for Outcomes Research and Education, Willamette Partnership, and Portland State University to model the predicted water, air, and health benefits of those activities.

At the current pace of greening, canopy cover is likely to increase 5% above 2014 levels (from 24% to 29% cover) by 2040. In the next 20 years[3], we expect those trees to create a 5 degrees Fahrenheit cooling effect and a 2.9 ppb reduction (about 13% from current) in nitrogen dioxide (NO_2) exposure. Just the reduction in NO_2 exposure alone could annually reduce 22 cases of exacerbated asthma when planted trees are mature in 2040. It is estimated that a 5% increase in canopy cover would reduce water pollutant loads for sediment, nutrients, and metals by 0.6% by 2040[4]. If the Jade District Greening effort increases its pace to meet the City's 33.3% canopy goal, we estimate a 1% reduction in stormwater flow and pollution loading. The estimated value of each street tree based on water, air quality, and heat benefits would be about $131/tree.



The Jade District is using a community-centered approach to greening, which is engaging an array of community members and leaders. On one Saturday, Friends of Trees led a community tree-planting. The event engaged about 150 volunteers over 3-4 hours to plant 127 trees. We surveyed 82 of those volunteers about their demographics, relationship to Friends of Trees, health, and opinions regarding trees in cities. When asked "How did the tree planting event make you feel?" 100% responded positively using words like "great," "awesome," "productive," and "accomplished." Some respondents also talked about stronger social connectedness. Ninety percent of respondents agreed that trees help shade and cool surroundings, clean air, and make people feel calm. The people who showed up to plant trees came in healthy and left healthy — a result that underscores the difficultly in tracking the causal link between time in nature and health without more robust evaluation and research design.

Going Forward

APANO and the Jade District greening partners will continue efforts to increase greenspace in the District and refining the ways they monitor, measure, and model the many benefits of their work.

[3]In the next 20 years (2040), we expect planted trees to be at 35% of their mature height and canopy spread.

[4]Total 2017-2018 plantings are estimated to reduce pollutant loads by 0.05%.

Appendix B: Jade District Tree Planting Evaluation: A Health and Outdoors Initiative Project

Jade District Tree Planting Evaluation
A Health and Outdoors Initiative Project

Background

The Jade District neighborhood of Portland, OR refers to the area in SE Portland surrounding 82nd and Division. One of the most diverse neighborhoods in Portland, the Jade District is approximately 40% communities of color, with a large mix of Asian cultures. In 2011 the Portland Development Commission designated the Jade District neighborhood a Neighborhood Prosperity (NPI) district. The purpose of this designation is to help revitalize underserved commercial districts in Portland while maintaining the cultural diversity of the neighborhood.

Due to the cultural makeup of the neighborhood, the NPI planners engaged APANO as partners in the revitalization project. APANO identified key targets for the improvement of the neighborhood, including partnering with Friends of Trees and the Willamette Partnership to host tree plantings, tree walks, tree care events, neighborhood clean ups, community gardens and backyard habit planning, traffic safety initiatives, and neighborhood meetings.

Previous research has demonstrated that tree planting not only increases the tree canopy and greenspace of a neighborhood, but may also impact the physical and mental health of neighborhood residents. As part of its ongoing relationship with CORE through the Health and Outdoors Initiative, the Willamette Partnership partnered with CORE to evaluate the Jade District revitalization project's first tree planting event.

Results

The tree planting event occurred on Saturday February 17, 2018. Like previous Friends of Trees tree planting events, the Jade District event engaged approximately 150 volunteers, lasted about 3-4 hours, and involved the planting of 127 trees. 82 adult volunteers responded to a survey asking them about their demographics, relationship with Friends of Trees, health, and opinions regarding trees in cities.

Demographics and Self-Reported Health

Few respondents (14.6%, n=12) lived in the Jade District neighborhood, with most respondents travelling from different Portland neighborhoods or nearby towns to participate in the event. The average age was 38 years old. The majority of survey respondents identified as male, White, and English speakers. Of note, the survey was only offered in English, which may have biased results. (Table 1)

Respondents indicated they had few depression, anxiety, and stress symptoms (Table 2). However, more respondents indicated that they ruminated on past experiences: about half of the respondents indicated they reflect on episodes of their life they should no longer concern themselves with (48.8%), and a little more than a third indicated they spend a great deal of time thinking backing over embarrassing or disappointing moments (36.6%).

Table 1: Demographics

	n	% mean±SD
Jade District Resident		
Yes	12	14.6
No	57	69.5
No Response	13	15.9
Gender		
Male	43	52.4
Female	38	46.3
Self-describe	1	1.2
Age		37.8 ± 13.3
Race		
White	59	72.0
Hispanic	5	6.1
Black	5	6.1
Asian American	5	6.1
American Indian/ Alaskan Native	2	2.4
Native Hawaiian or Other Pacific Islander	1	1.2
Self-describe	6	7.3
Language*		
English	76	95.0
Mandarin	3	3.8
Other	3	3.8

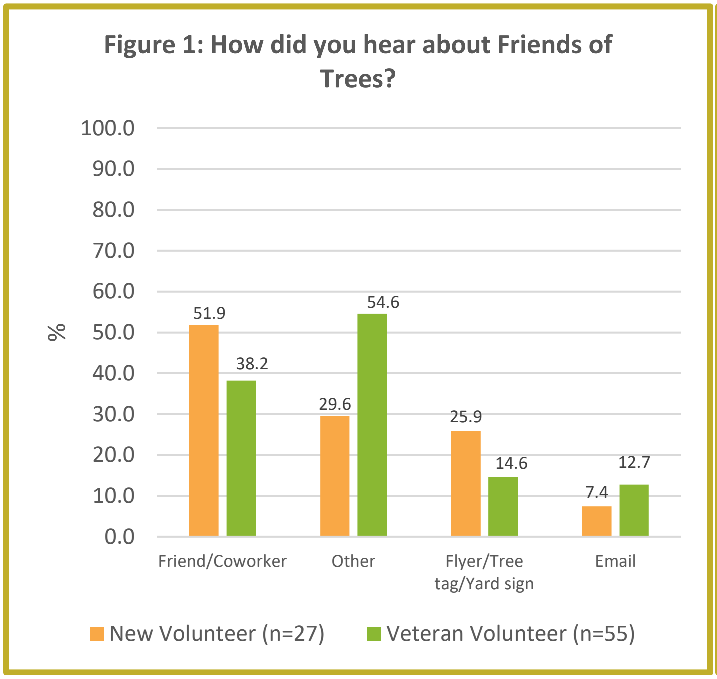
*Surveys were only offered in English

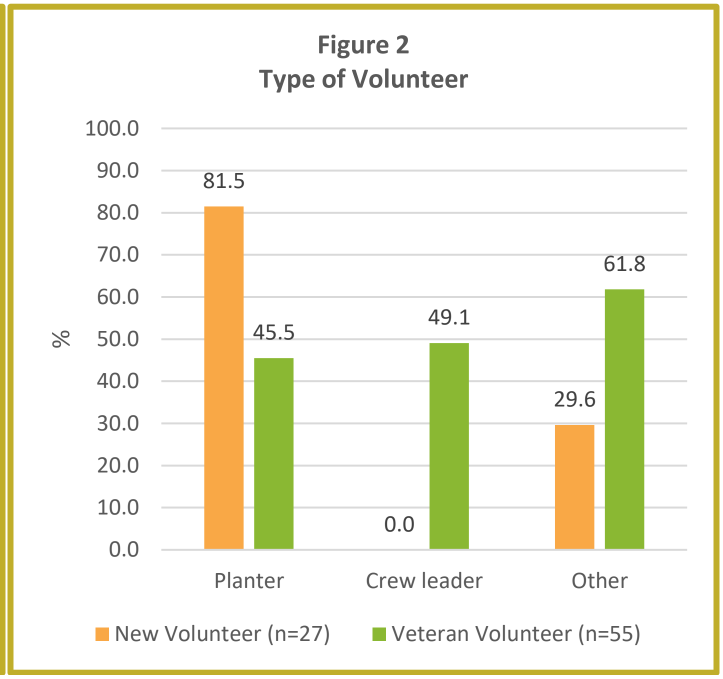
Table 2: Self-Reported Mental Health

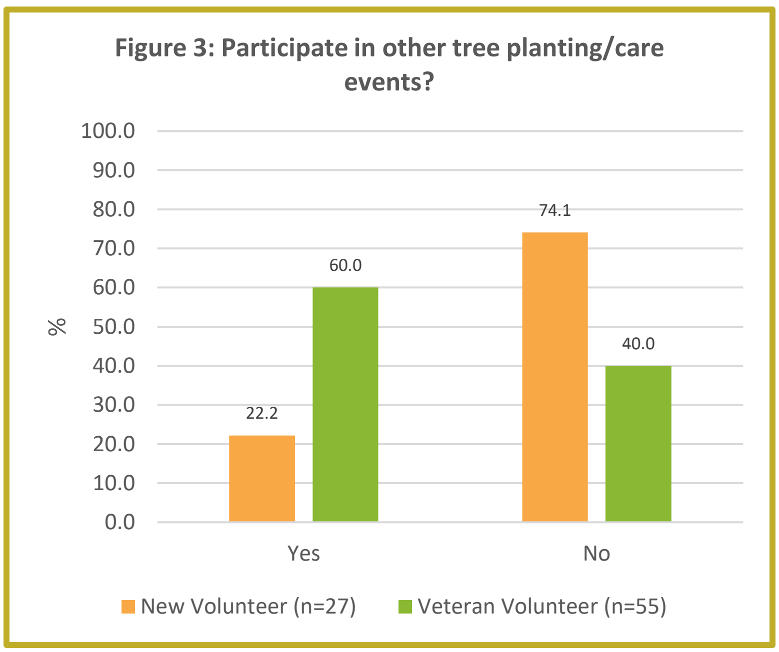
	mean±SD
Depression symptoms (0-6)	0.73 ± 1.00
Anxiety symptoms (0-6)	1.13 ± 1.36
Stress symptoms (0-16)	4.92 ± 3.01

Relationship with Friends of Trees

About one-third of respondents (32.9%) were first time Friends of Trees tree planting/care event participants. Across the entire sample, a friend or coworker was the most common avenue in which respondents heard about Friends of Trees (42.7%), The majority of the new volunteers (81.5%, n=22) were tree planters, while about half of veteran volunteers were crew leaders (49.1%) (Figure 2). More veteran volunteers indicated they currently participate in other tree planting/care events than new volunteers (Figure 3). However, almost all respondents said they were interested in participating in future tree planting events (92.7%).



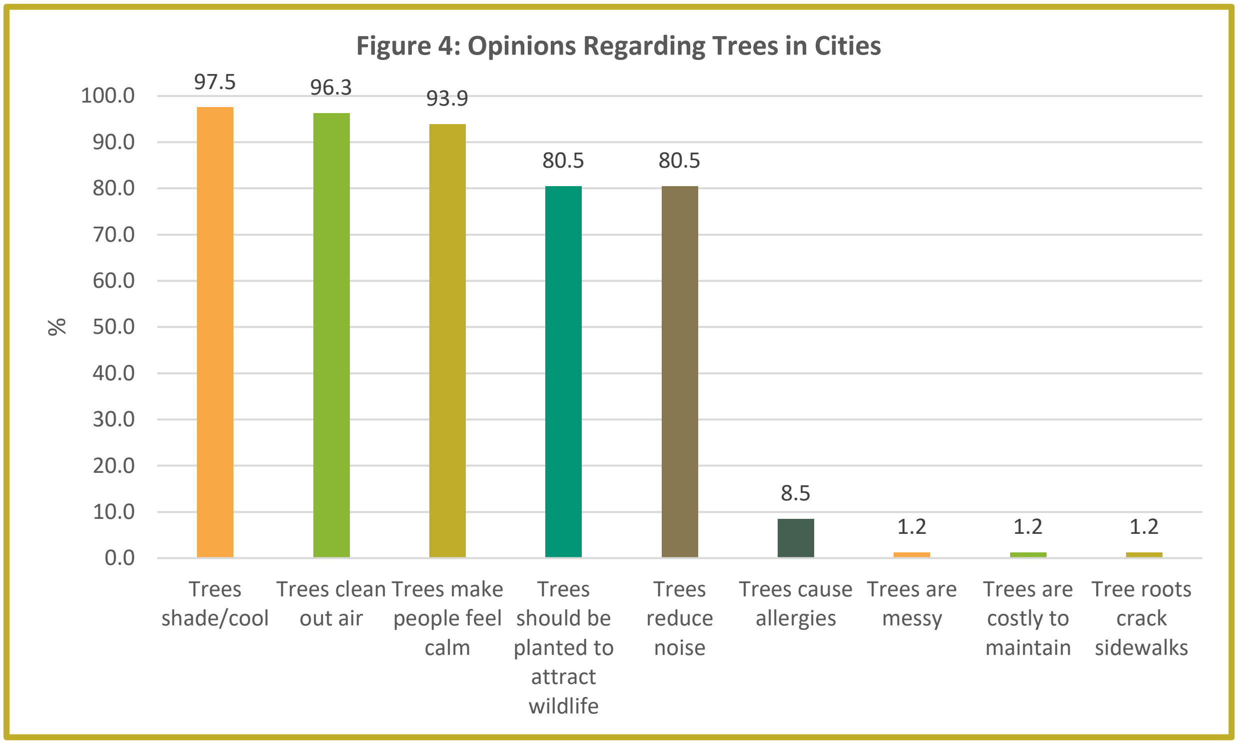




Overall respondents had positive things to say about the tree planting event. Among the 74 respondents who answered the open ended question: “How did the tree planting event make you feel?”, 100% responded positively, using words like “great”, “awesome”, and “wonderful.” Respondents also indicated that the event made them feel “productive” and “accomplished”, and that they enjoyed being part of an environmentally conscious community. Some participants also stated that the event made them feel more connected to the neighborhood and community.

Opinions regarding trees in cities

Respondents were asked about their opinions regarding trees in cities (Figure 4). Overall, respondents agreed more with statements that mentioned the positive effects of trees in cities, rather than the negative. For example, over 90% of respondents agreed that trees help shade and cool their surroundings, clean the air, and make people feel calm; while less than 2% of respondents agreed that trees are messy, costly to maintain, and crack sidewalks with their roots.



Jade District: Tree Planting
Baseline Survey

Instructions: This survey will help us learn more about the benefits of community tree planting events. For each question, please fill in the box that best represents your answer. Your results are *completely private*, and you can skip any question. When you are finished with the survey, please give the survey back to a Friends of Trees staff person.

Part 1: Tree Planting with Friends of Trees

1. How did you hear about **Friends of Trees**? *Mark all that apply.*
- ❑ Facebook/Social Media/NextDoor
- ❑ Email
- ❑ Flyer
- ❑ From a friend
- ❑ Friends of Trees yard sign
- ❑ Friends of Trees tree tag
- ❑ Someone spoke to me at my home
- ❑ Other: _________________________________ (please tell us)

2. What type of volunteer are you? Mark all that apply:
- ❑ Tree planter
- ❑ Crew Leader
- ❑ Tree recipient
- ❑ Tree pruner
- ❑ Part of a volunteer group

3. How many tree planting/care events have you participated in?
- ❑ This is my first one
- ❑ 1-2 total
- ❑ 3-6 total
- ❑ I volunteer Once/twice a month
- ❑ I volunteer Every week
- ❑ Other:_______________ (please tell us)

4. Do you participate in other community and environmental events (i.e. clean up, invasive species removal, etc.)?

- ❑ Yes --------If so, what types of events: ____
  ____
- ❑ No

5. How did the tree planting/care event make you feel? _______________________________________
____

6. Do you plan to care for the trees you helped plant?
- **a.** Yes
- **b.** No
- **c.** N/A

Participant's Name:___________________________________

7. Do you want to participate in more tree planting events in the future?
   a. Yes
   b. No

Part 2: Being Out in Nature and Opinions Regarding Trees in Cities

8. For each of the fowling, please rate the extent to which you agree with each statement

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. Trees are important because they shade and cool their surroundings.	❑	❑	❑	❑	❑
b. Trees in cities help people feel calmer.	❑	❑	❑	❑	❑
c. Trees are a problem in cities because they cause allergies.	❑	❑	❑	❑	❑
d. Trees should not be planted in cities because they are messy and drop leaves and residue.	❑	❑	❑	❑	❑
e. Trees should not be planted because they are too costly to maintain.	❑	❑	❑	❑	❑
f. Trees should be planted in cities to attract wildlife.	❑	❑	❑	❑	❑
g. Trees should be used in cities because they reduce noise.	❑	❑	❑	❑	❑
h. Trees should not be planted because their roots crack sidewalks.	❑	❑	❑	❑	❑
i. Trees should be planted in cities because they help clean our air.	❑	❑	❑	❑	❑

9. Thinking about the **neighborhood that this tree planting event occurred in**, please rate the extent to which you agree with each statement.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. I love living here in this neighborhood	❑	❑	❑	❑	❑
b. I would find it a great pity if I had to move away.	❑	❑	❑	❑	❑
c. My neighborhood is very special to me.	❑	❑	❑	❑	❑
d. I would recommend this neighborhood to my friends as a living place	❑	❑	❑	❑	❑
e. I feel very attached to my neighborhood	❑	❑	❑	❑	❑
f. My neighborhood means a lot to me	❑	❑	❑	❑	❑
g. I do not want to live in another place	❑	❑	❑	❑	❑

Participant's Name: ____________________________________

Part 3: Your Health and How You're Doing Now

10. During the **past 2 weeks**, about how often have you been bothered by the following problems:

	Not at all	Several days	Over half the days	Nearly every day
a. Little interest or pleasure in doing things	❑	❑	❑	❑
b. Feeling, down depressed or hopeless	❑	❑	❑	❑
c. Feeling nervous, anxious, or on edge	❑	❑	❑	❑
d. Not being able to stop or control worrying	❑	❑	❑	❑

11. In the **past month**, how often have you:	Never	Almost never	Sometimes	Fairly often	Very often
a. Felt that you were unable to control the important things in your life?	❑	❑	❑	❑	❑
b. Felt confident about your ability to handle your personal problems?	❑	❑	❑	❑	❑
c. Felt that things were going your way?	❑	❑	❑	❑	❑
d. Felt difficulties were piling up so high that you could not overcome them?	❑	❑	❑	❑	❑
e. Reflected on episodes of your life that you should no longer concern yourself with?	❑	❑	❑	❑	❑
f. Spent a great deal of time thinking back over your embarrassing or disappointing moments?	❑	❑	❑	❑	❑

Part 4: About You

12. What year were you born? ______

13. Which of these describes you?

❑ Male

❑ Female

❑ Transgender or gender non-conforming

❑ I prefer to self-describe ______________________

Participant's Name: ___________________________________

14. How do you describe your race/ ethnicity? *Mark all that apply.*

- ❑ White
- ❑ Hispanic, Latino, or Spanish origin
- ❑ Black or African American
- ❑ Asian
- ❑ American Indian or Alaska Native
- ❑ Middle Eastern or North African
- ❑ Native Hawaiian or Other Pacific Islander
- ❑ I prefer to self-describe _______________________

15. What language do you speak best? *Mark only one*

- ❑ English
- ❑ Spanish
- ❑ Mandarin
- ❑ Vietnamese
- ❑ Other: _________________________

16. What is the closest major intersection to your house? ___________________________________

17. We will ask participants to take a follow-up survey in a few months. Please provide us with an email or text-capable cell phone. We would greatly appreciate your participation in our follow up survey.

Cell phone (include area code):_______________________________
E-mail:____

Participant's Name: ___________________________________

Appendix C: Modeling the Effects of Trees on Air Quality and Extreme Heat Change in the Jade District

Modeling the Effects of Trees on Air Quality and Extreme Heat Change in the Jade District

Vivek Shandas, Joey Williams, Jackson Voelkel

1. Background

Within the context of a changing climate, population growth, and rapid land use change, the management of our urban atmosphere is one of the grand challenges facing society. A key aspect of managing the urban atmosphere is understanding the pathways through which degraded air quality and extreme temperatures increase human vulnerability, while affecting health and well-being. For decades, studies of human vulnerability suggest that communities that are consistently exposed to degraded air pollution and extreme thermal conditions encounter more health-related challenges than all other environmental factors combined (Cutter 2003; Klienenberg, 2004; Polsky et al., 2010). Urban heat by itself claims more lives than all other natural disasters put together. As such, recognizing the exposure pathways, and the opportunities for mitigating the potential harmful effects of degraded environmental conditions is paramount. Indeed, as our cities warm, our built environment will amplify temperatures and further degrade air quality unless communities can pro-actively intervene with promising solution.

One promising approach to improve urban environmental conditions is the intentional placement of trees within neighborhoods. Using extensive evidence from dozens of cities worldwide, community groups, cities, and businesses are planting trees with the aim of cooling neighborhoods and cleaning the air. These mechanisms (of cooling and cleaning) are well understood, yet, a few challenges remain. First, few projects have developed an international equity-based approach for advancing tree planting strategies. Several reports indicate that even with well-understood 'ecosystem services' from trees, their historical placements occur primarily in wealthy areas of cities. Second, frameworks and analysis about the ameliorative effect of trees at the neighborhood scale remain a largely unexplored area of research. Does the increase of tree canopy by 10% in a neighborhood actually improve air quality? How about the extent of cooling during a heat wave? These questions point to the fact that many investigations of the ameliorative effect of trees occur either at the city scale or within chamber studies that examine the role of an individual tree. Arguably, without the quantification of the relationship between tree plantings and potential future benefits at the neighborhood scale, communities have to take on good faith that their greening efforts will [eventually] improve their health and well being..

The present project aims to provide a quantitative assessment of a community-supported tree planting campaign, which aims to reduce the concentrations of a particular air pollutant (nitrogen dioxide, NO_2), and changes in ambient temperatures. We ask, to what extent does neighborhood scale tree plantings improve air quality and reduce temperatures now and into the future? By using a case study of the Jade District in Portland, OR, and the extensive greening efforts to date, we are building on existing empirically-based data on air quality (NO_2) and temperatures, to address the question. Specifically, we conduct three major tasks. First, we integrate extant datasets necessary to model the air quality change for NO_2 and extreme heat, including tree planting locations, growth rates of individual species, and projects of canopy volume and ameliorative effect 20 years into the future. In addition, by selecting a specific area of the Jade District, we calibrate a microclimate model (ENVI-Met) to describe the distribution of temperatures during a heat event – defined here as a day above 90°F. The calibration requires careful analysis of each of the building, landscape, and land cover parameters, which together can help us to predict ambient temperatures in the Jade District. Second, we use tree growth projections for estimating how, over the course of two decades (2040), the greening efforts impact exposure to air pollutants and temperatures across the whole district. These growth projections, drawn from the literature and experts (i.e. arborist, city forestry staff, etc.) will be associated to relevant changes in air quality and urban heat. Although health benefits will not be a direct outcome of these estimates, based on capacity and data quality, we apply BenMAP -- a tool developed by the US Environmental Protection Agency -- to characterize health benefits accruing from changes to the greenery in the Jade District.

During the process, we shared an initial estimate of the outcomes with the Willamette Partnership team and a small set of Jade District stakeholders, including a member from the Asian Pacific American Network of Oregon (APANO) and City of Portland staff responsible for tree plantings in the District. The remainder of this report consists of a summary of the methods employed, and a series of maps of the anticipated effects from initial tree plantings and other greening projects. We offer these outcomes as a means for identifying approaches that are applicable to other cities, many of whom are initiating or expanding tree planting, though with currently no capacity to assess potential effects on local environmental conditions.

Figure 1: Defined boundaries for analyses

2. Methods Employed

2.1 Modeling Microscale Changes to Temperatures

Table 2.1: *Summary of information/datasets required to run each analysis*

Analysis (scale applied)	**Information/Dataset**	**Source(s)**
Heat exposure modeling using ENVI-Met (Study area & focus block)	Site boundary and cell size	User input
	Land cover	LiDAR/Metro Regional Land Information System (RLIS)
	Building heights	LiDAR/RLIS
	Deciduous/coniferous canopy	LiDAR/RLIS
	Mature height/width of new plantings	User input (expert informed)
	Projected growth rates of new plantings	User input
	Potential locations of new plantings	Branch Out PDX: Plantability
	Materials of buildings, soils & surfaces	Default data via ENVI-Met
	Initial temperature and wind-speed	Weather Underground
NO_2 modeling (district-wide)	Canopy cover raster	LiDAR/RLIS
	NO_2 raster	District-Wide NO2 Analysis Output
	Impervious surfaces	LiDAR/RLIS
Urban Heat Island modeling (district-wide)	Canopy cover raster	LiDAR/RLIS
	Urban Heat Island raster	PSU SUPR Lab
	Impervious surfaces	LiDAR/RLIS
BenMAP (district-wide)	Pre- increased canopy NO_2 concentrations raster	NO_2 Analysis Output
	Post- increased canopy NO_2 concentrations raster	NO_2 Analysis Output
	Demographic Data	PopGrid (BenMAP default)
	Initial health incidence functions	BenMAP default
	Valuation functions	BenMAP default

Using a computational fluid dynamic (CFD) model, ENVI-Met, the impact of canopy coverage on ambient temperatures in the Jade District may be simulated at the block scale. A 200m by 200m single-family residential area between Southeast 80th and 81st Avenue at Division Street was chosen as the study area (Figure 2.1). This area was selected because it contained the hottest temperatures, and had the most potential for increasing canopy cover. To account for the impact of surrounding land covers, we constrain the area to the center block, or “focus block” (purple line, Figure 2.1). Knowing that trees or driveways across the street from a property can provide cooling and heating effects on the residence, including the adjacent land covers is important for accurately simulating a block of this size. While ENVI-Met will simulate conditions for the entire study area, for this reason, interpretable results are limited to the focus block. Note that within this study area, some parcels and streets contain significant canopy coverage, while others are sparsely covered or feature no canopy at all.

Figure 2.1: Residential study area and focus block.

To create a baseline scenario, a bitmap image of the study area (Figure 2.2) is digitized in ENVI-Met with delineations of ground cover at a resolution of 2m x 2m. This cell size is chosen due to the restriction of 100 rows and 100 columns by ENVI-Met and the desired study area of 200m by 200m. Characteristics of existing land cover are provided by Metro's Regional Land Information System (RLIS) with existing canopy height in 5m increments and building height in 1m increments. Existing canopy is characterized as deciduous or coniferous and the building material is set as hollow-block cinder by default. The remaining surfaces are classified as either black asphalt (road), light pavement (sidewalks), or low vegetation (<20cm grass). A summary of these inputs, as well those for the subsequent analyses, is found in Table 2.1.

Three different growth scenarios were developed for this baseline model. The growth scenarios consisted of increasing canopy cover by 5%, 10% and 15% to correspond with meeting Citywide canopy targets of 33% -- currently the area contains approximately 22% canopy cover. The scenarios offer a means for assessing how changing canopy cover in this area can reduce temperature, thereby providing District decision makers targets for implementing future tree planting efforts. A 15% increase in canopy would raise the District to 37% canopy coverage, four points higher than the Citywide target. With this consideration and the limitation of time, the 15% scenario was most explored in analyses. Enhancing the resilience of the Jade District, where the population is statistically more vulnerable to the impacts of extreme heat, provides an equitable approach to implementing increases in canopy coverage.

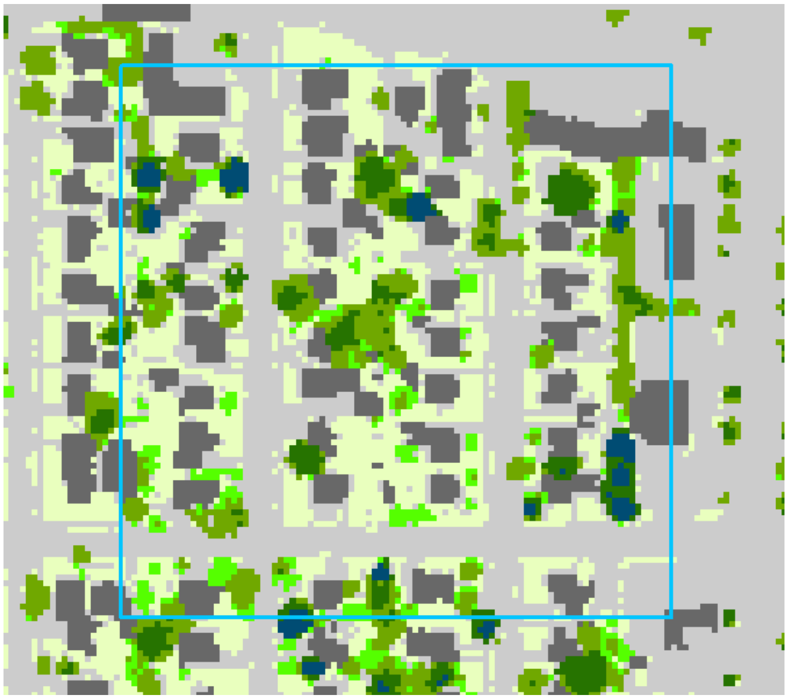


Figure 2.2: Two-dimensional image of the study area (2m x 2m cells).

Developing the scenarios required an understanding of where trees may realistically be located, without changing current landforms, including the distribution of hardscapes (i.e., asphalt, concrete, etc.). To identify potential planting locations, we employed a tool recently created by the City of Portland in collaboration with the Sustaining Urban Places Research Lab. The tool, called the Branch Out PDX Map, allows filtering of plantable locations by environmental factors, including percent canopy cover, urban heat index and, air pollution index; social factors at the Census block group level such as median household income and percent people of color; and parcel level variables of location (street or parcel), occupancy (renter or owner), residence (single- or multi-family), and roads (under-improved or improved). Specific criteria in this scenario included street-side locations with <2% tree cover along the public areas (no private locations), high urban heat and NO_2 levels. The resulting map describe specific locations within a city block that contains the potential for expanding the tree canopy (Figure 2.3).

Figure 2.3: Plantability tool displaying filtered available planting locations.

The dimensions of modeled plantings is based on the average species' spread and height at 35% maturity of recent plantings (2014 - 2018) in the Jade District. Within the ENVI-Met digitization, each new planting was modeled with a spread of eight meters and height of ten meters. As recent plantings in the Jade District consisted primarily of deciduous trees, the plantings simulated similar default leaf characteristics. To determine the quantity of unique new plantings, the area of increased canopy coverage was divided by the new planting area of $80m^2$, which was the area that was considered plantable. New plantings are then placed within the areas designated by the Branch Out PDX Map results. The output provides a digitized baseline and 15% growth scenario maps (Figures 2.4 and 2.5)

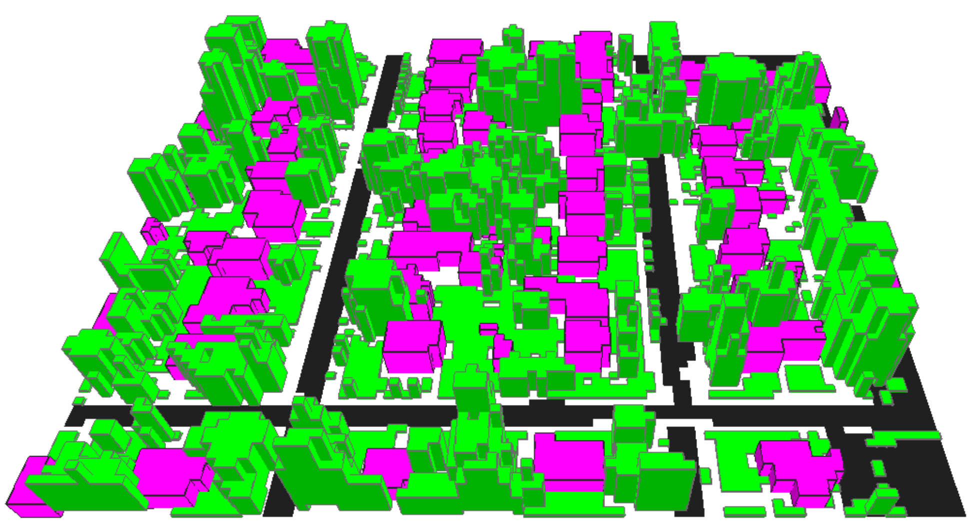


Figure 2.4: Digitized (ENVI-Met) map of baseline (3D view).

Figure 2.5: Digitized (ENVI-Met) map with 15% growth scenario (3D).

Configuration files for the baseline and 15% growth scenario are then created to simulate historical weather conditions at the study area for August 3rd, 2017, the hottest day of the last calendar year. Historical data collected from the South Tabor weather station (WeatherUnderground™) provided an initial temperature of 28°C and average wind direction of west/northwest (290°). The model initiates under these conditions and simulates the interactions between atmosphere, soil, vegetation and buildings on a microscale level second-by-second for a 24-hour period (Huttner, 2012). The predicted wind speed and direction, air and soil temperature, humidity, turbulence, and radiative flux is stored cell-by-cell and can be visualized using the complementary software tool, Leonardo.

To determine the attributes of the trees modeled in the subsequent analyses, we examined each species of tree that was planted within the Jade District from 2014 to 2018. Results from a breadth of online resources, namely gardening and nursery retail websites, were compiled into a spreadsheet for each individual tree. Next, a Master Arborist was consulted to determine the projected height and spread of each tree species 20 years after planting in an urban environment. Using the arborist's estimate of trees generally reaching 35% maturity given these conditions, each tree species' height and crown were multiplied by 0.35. The resulting dimensions were used for the following analyses.

3. Changes to Microscale Temperature

Visual outputs of the baseline and 15% growth scenarios illustrate the expected cooling effect of areas nearby to new plantings. The output illustrates the difference in temperature at 1.4 meter elevation (pedestrian level) between the two scenarios at the warmest part of the day, 5:00 P.M (Figure 3.0). The circular green and blue areas, indicating cooling between the baseline and 15% growth scenario, correspond with the locations of new plantings. Reduction in temperature at each grid cell is measured in degrees-Kelvin, though discussed throughout in degrees-Celsius

(1:1 in scale). The range in predicted reductions across all cells in the study area is from a minimum predicted reduction of 0.18°C to a maximum predicted reduction of 1.18°C.

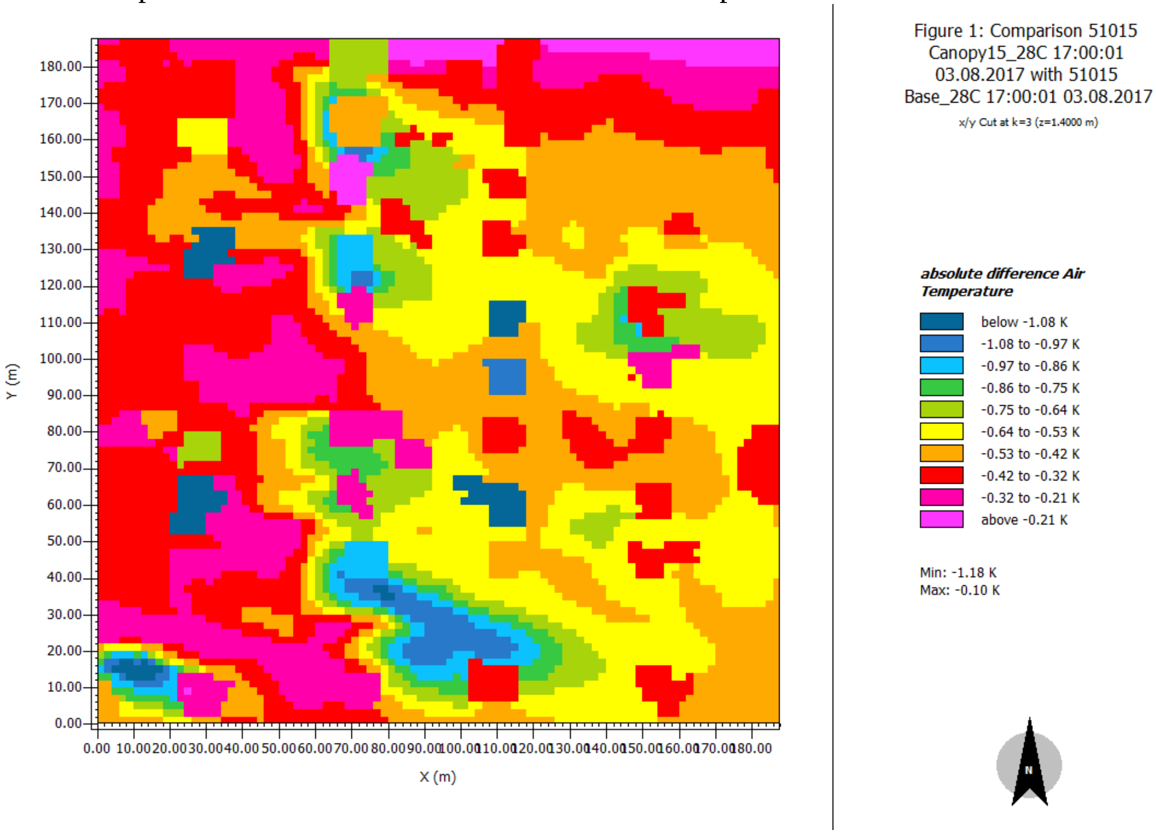


Figure 3.0: Comparison of 15% growth scenario to baseline.

3.1 Alternative Scenario 1: Strategically Locating Trees

An alternative method for determining the locations of new plantings is to simulate the baseline with the stated conditions (Figure 7), and use the map results to identify the warm places within the focus block.

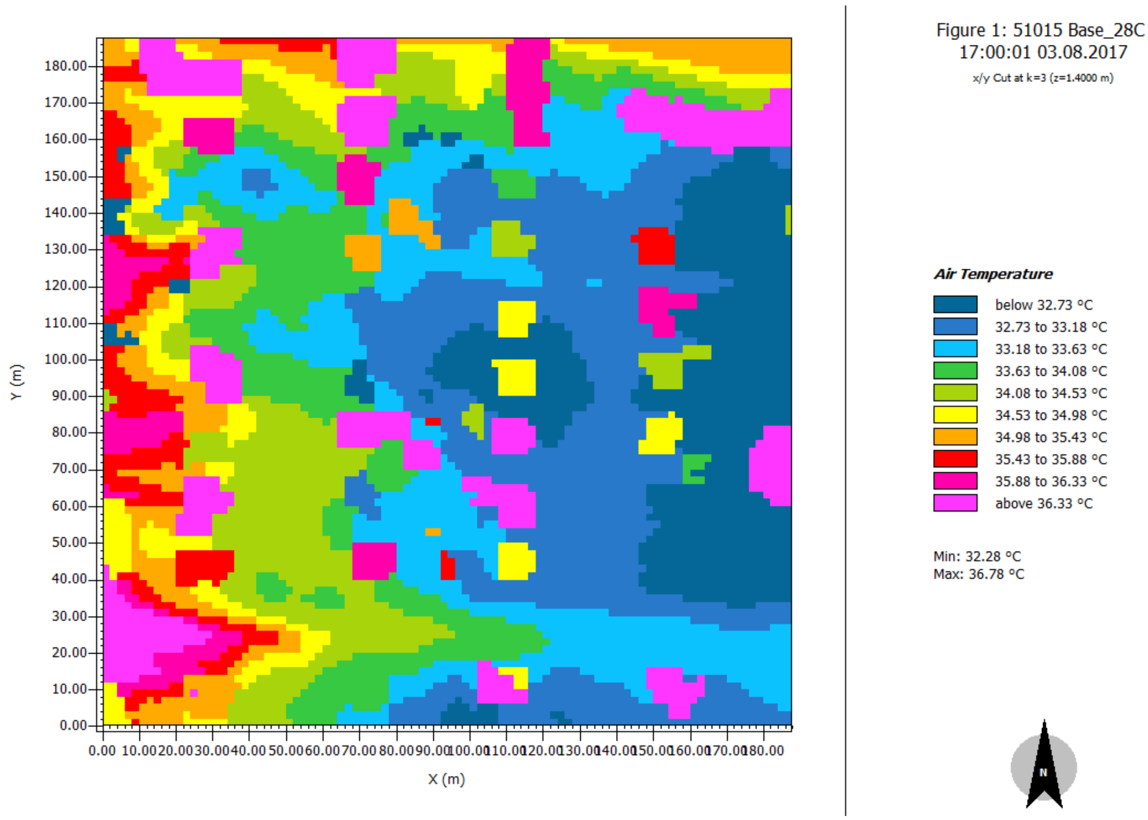


Figure 7: Comparison of 15% growth scenario 1st alternative to baseline.

Noting the warmer locations near the southwestern corner of the focus block, new plantings were modeled at street-side locations as well as at locations identified by the Plantability tool (Figure 8).

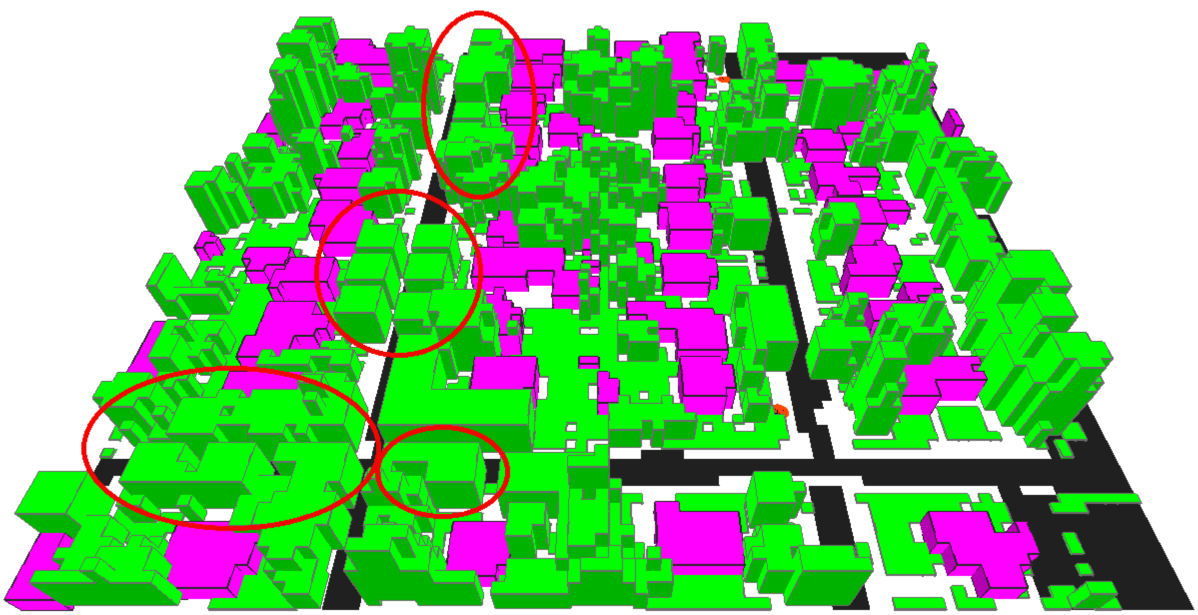


Figure 8: ENVI-Met 15% growth scenario 1st alternative 3D view.

The map results of the strategic planting simulation describes a significant cooling in green and blue at the targeted areas (Figure 9). The maximum predicted reduction of this scenario compared to the baseline is 1.29°C. The results suggest that targeting plantings in the hottest areas of the focus block may provide greater cooling benefits, than random placement of trees.

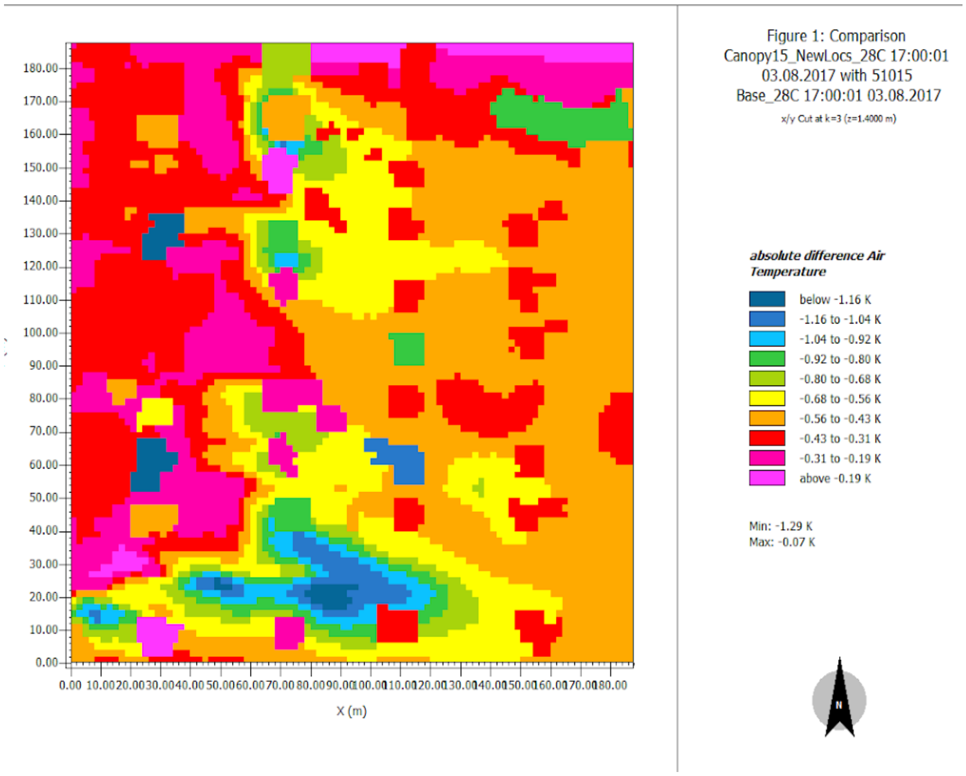


Figure 9: Comparison of 15% growth scenario with targeted plantings in hottest areas.

3.2 Alternative Scenario 2: Strategically Planting Fast Growing Trees

By modeling the same planting locations as Alternative Scenario 1, we might ask what would occur to the temperatures if we planted faster growing trees. By matching the planting height of the larger trees growing in the focus block (20m), this scenario includes a faster growth rate, over a longer timeframe, or of a taller species -- all of which bring more biomass within a shorter period into the study site.

As compared to the baseline conditions, the results suggest a maximum predicted reduction of 1.35°C. This alternative suggests that strategically planting trees in the hottest areas, and considering fast growing species (or generally larger growing trees), provides the greatest cooling.

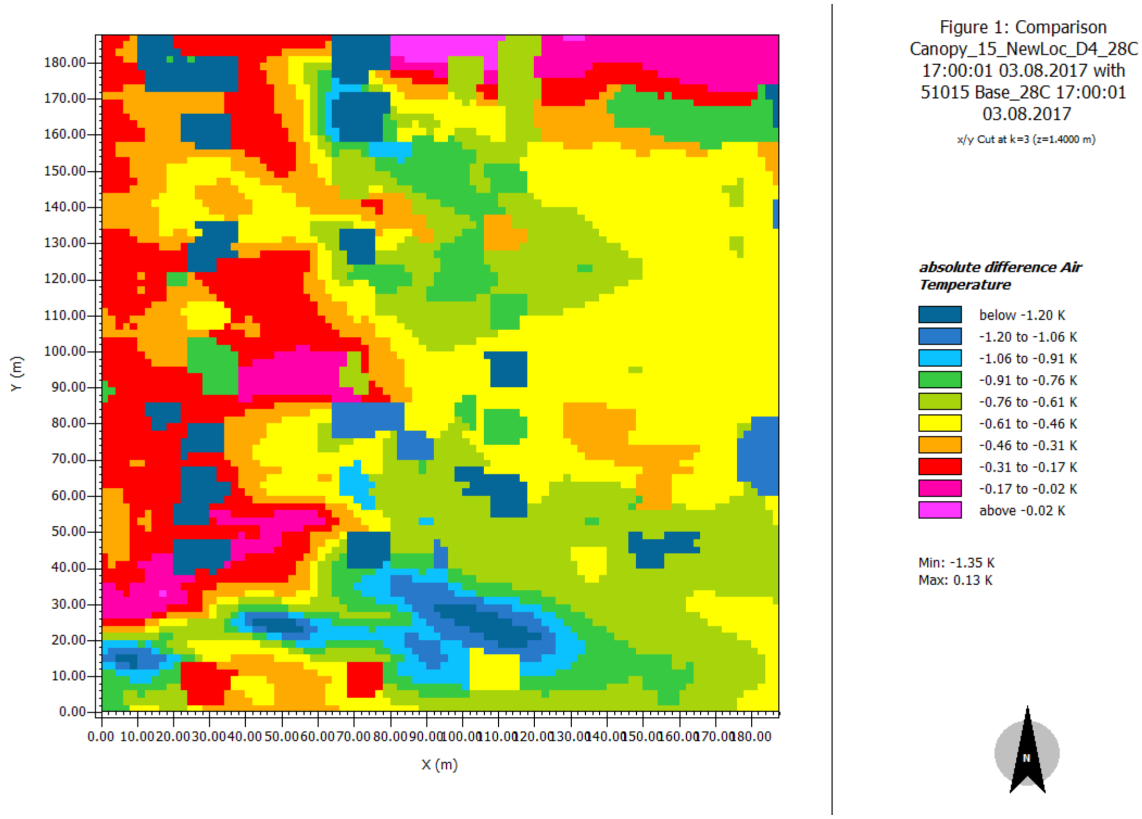


Figure 10: Comparison of Alternative 2, 15% growth scenario with tall trees, in new locations, to baseline.

4. District-Wide Changes to Urban Heat and Air Quality

Area-wide estimates are those which take into consideration the entire Jade District in order to model and predict future changes in temperatures and NO_2. While current definitions of the Jade District vary by context, it is here defined as the geographic region east of Southeast 79th Avenue, west of Interstate 205, north of Southeast Ramona Street, and south of Southeast Market Street. This rectangular boundary includes US Census Block Groups that are located near or within other definitions of the District.

4.1. Growth Scenario Data

In order to estimate the effects of present and potential future tree cover in these models, we created planting scenario raster datasets with a baseline of tree cover as provided by RLIS. These were consistent with the local-area scenarios including increases in canopy cover of 5%, 10%, and 15%. First, we created the baseline canopy cover dataset by combining current canopy cover with the growth-projected plantings (Section 2 above). The baseline tree locations combined with an impervious surface layer, also from RLIS, to determine all potential plantable spaces in the Jade District[1]. Once (a) baseline canopy cover and (b) plantable spaces are located,

[1] For the purposes of this study, "plantable spaces" are determined to be those with neither impervious surface nor canopy cover. The authors recognize that there is absolute potential for the removal of impervious surfaces or canopy cover, though the prediction and modeling of such scenarios falls outside of the scope of the present analysis.

random pixels are added to plantable spaces. These random pixels are added three separate times with differing amounts totaling 5%, 10%, and 15% (35,225px, 70,450px, and 105,675px respectively; Figure 11). We then merged the 'growth scenario' datasets, the baseline description, and the three randomized planting location maps. The results of this analysis are:

- A **baseline datasets** representing the combination of current canopy and the additional recorded plantings
- A **5% increase** over the baseline, with trees only added to plantable spaces.
- A **10% increase** over the baseline, with trees only added to plantable spaces.
- A **15% increase** over the baseline, with trees only added to plantable spaces.

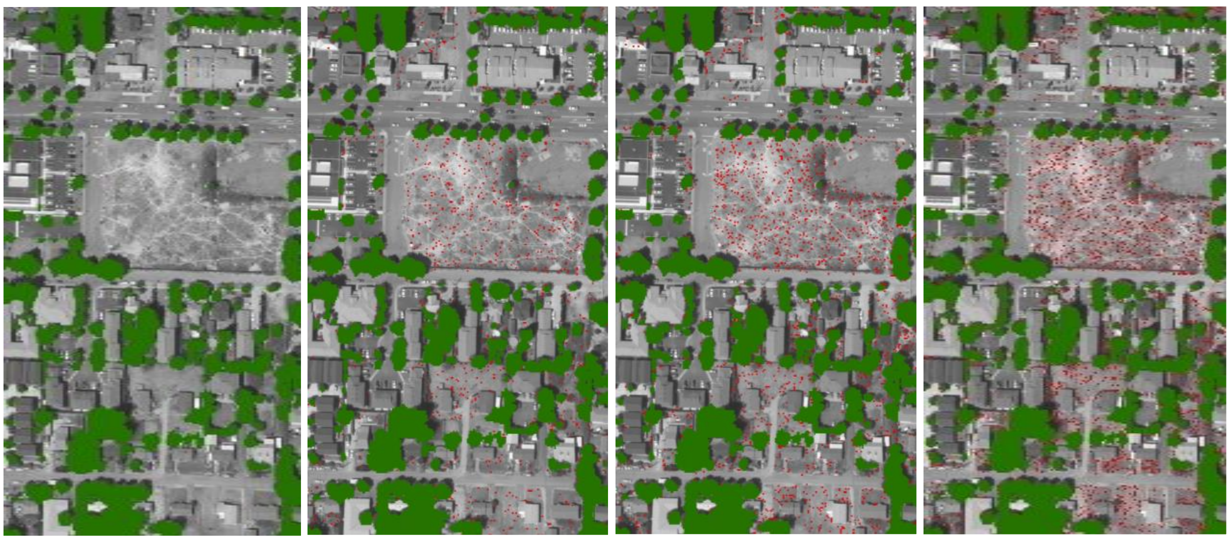


Figure 11: Projected baseline (green), random pixels (red); ***from left to right****:* 0%, 5%, 10%, and 15%;

4.2. Modeling Changes to District-Wide Temperature

The modeling technique followed an approach originally developed by Voelkel and Shandas (2017). The process utilizes gridded maps (or rasters) of UHI and canopy cover to produce 15 rasters for each modeling instance (i.e. the baseline or 5% scenarios). Each of these new rasters are fed into the pre-existing model from the aforementioned approach, and temperature predictions on a pixel-by-pixel basis are output as a new raster dataset. The focus of the analysis is in the change in canopy cover, which the model modifies from the baseline raster. As a result, the model provides a predicted temperature for each cell, and the *temperature reduction due to the presence of canopy*. The reductions due to canopy cover is an important measure since one central part of the present analysis is to assess the possibility of improving ambient environmental conditions and potential exposure to communities.

4.3. Modeling Changes to District-Wide NO_2

The modeling technique to assess changes in NO_2 employed an approach that was developed in Rao et al. (2014) and utilizes input rasters of NO2 and canopy cover. The approach uses land use regression model to describe the influence of a multitude of variables on nitrogen dioxide (NO_2), including the effect of canopy cover. According to their calculations, NO_2 is expected to decrease $5.73 * 10^{-6}$ppb for every $1m^2$ increase in canopy cover within a $400m^2$ area. Using this canopy effect coefficient, a simple mathematical calculation transforms the abstracted layer (showing ‘percent canopy cover within 400m’ per pixel) into NO_2ppb reduction due to trees within the Jade District.

4.4. Results of Changes in District-Wide Temperatures and Air Quality

Not surprisingly, any increase from the baseline canopy percentage, reduces overall temperature in the district, though of note is the level of change across the scenarios. At 5% and 10% increases in canopy cover, the model predicts reductions in temperatures of 2.65°C and 2.79°C respectively. Interestingly, however, the 15% canopy model does not exhibit this behavior: it has a maximum predicted reduction of 2.74°C. The most likely explanation for this inconsistency is that the randomization of ‘tree’ pixels has had an effect on the resulting datasets. This could point to the concept that configuration of tree canopy has impacts on neighborhood-level cooling effects, although there are also many complex qualities and interactions of the urban environment that are difficult to express within this model. Further research and evaluation must take place to fully assess these phenomenon.

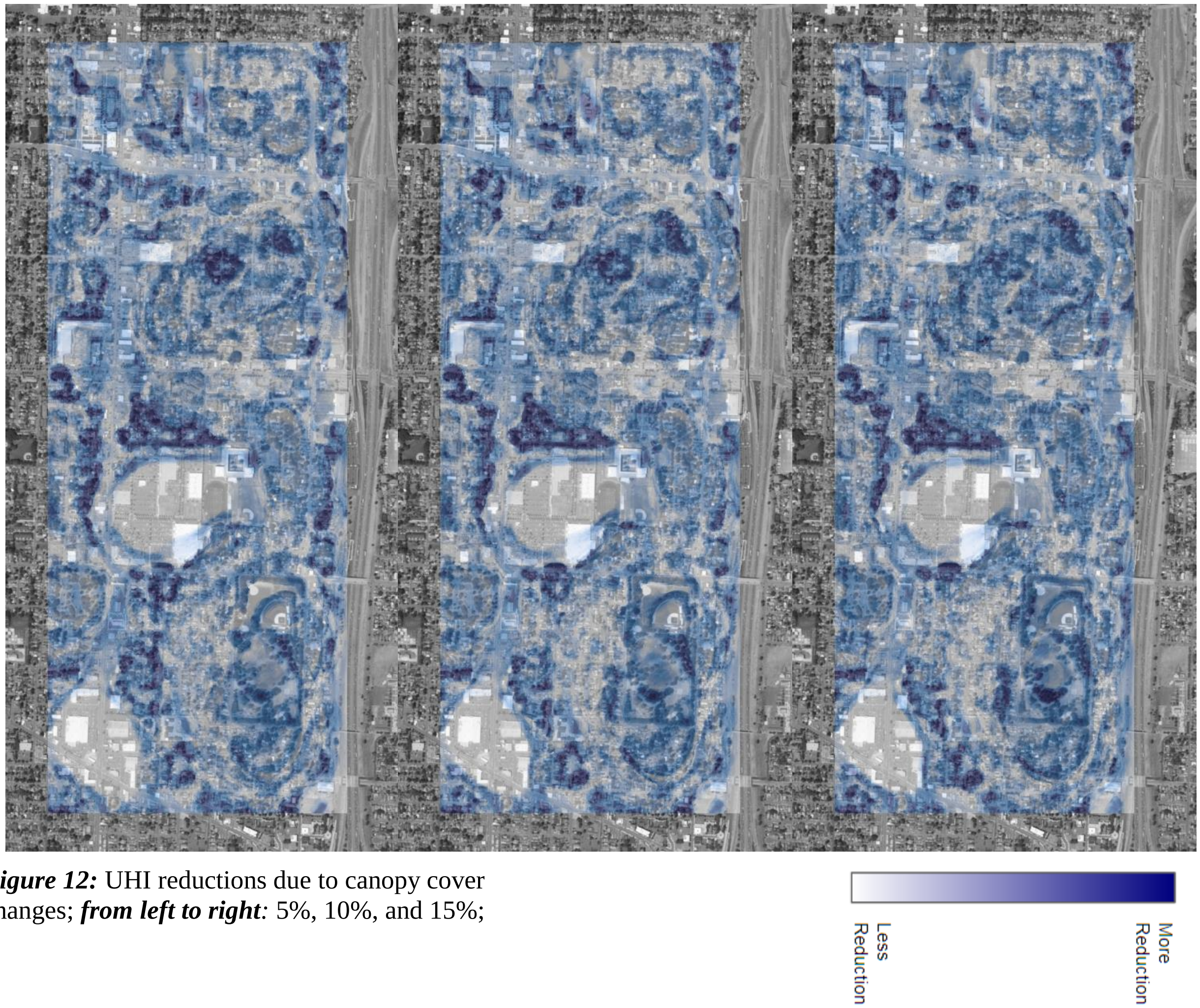


Figure 12: UHI reductions due to canopy cover changes; ***from left to right***: 5%, 10%, and 15%;

Because of the observed inconsistency in cooling patterns, one more model was created to show the cooling effects if canopy increased by 78% to cover 100% of all plantable spaces. Based on the average ground cover of trees planted in the area after 20 years of growth

($75.43m^2$) and the total plantable area ($704{,}500m^2$), we estimate that it would take approximately 9,340 trees to reach full stocking levels. When considering the full mature size of the average tree ($615.85m^2$), we estimate an additional 1,144 trees to reach full stocking levels. This model has a maximum predicted reduction of 4.8°C.

Similar results are also apparent in term of changes to NO_2. The reduction in NO_2, while slight, are still relevant to the overall aim of introducing canopy for addressing persistent challenges in air quality (Table 1).

Table 1: NO_2 reductions for three canopy cover increase scenarios.

Canopy Cover Increase (%)	**NO_2 Reduction Due to All Canopy (ppb)**
5	1.09986
10	1.12598
15	1.16348

Of note is that these are average reductions across the whole district. If applied to individual locations, the results might be higher. Also, these results do not take into account any other changes (e.g. land use, transportation activity, fleet mix, etc.), which, if included, may change the outcomes. Regardless, 1 ppb is approximately a 5% reduction in NO_2 among the areas of highest pollutant concentration in Portland and may provide significant alleviations to stressors. The health impact of these findings are further explored in the following BenMAP analysis.

5. Potential Health Improvements with Tree Plantings

Using the NO_2 area-wide results from Section 4 together with BenMAP 4.0, a health impact assessment tool from the US Environmental Protection Agency (EPA), the relative health effects and associated economic value of a 15% canopy cover increase in the Jade District were estimated. With equity considerations and limited time, 15% was chosen for this preliminary modeling, though 5% and 10% increase scenarios could be explored in subsequent analyses. Consistent with the extant literature, the health effects examined in this analysis included: acute respiratory symptoms, asthma exacerbation, emergency room visits, and hospital admissions. To calculate the reduced rate of the health effect, BenMAP combines user inputs of NO_2 levels along with program default data through a method simplified as:

Health Effect (change in incidence) = Air Quality Change *Health Baseline Incidence* Health Effect Estimate * Exposed Population

Where "Air Quality Change" is the difference, in this case, between NO_2 levels of the baseline and 15% canopy cover growth as provided from the District-Wide analysis and results. BenMAP compares the pre- and post-intervention values of NO_2 at each of 63,360 $20m^2$ resolution cells sampled across the area (Figure 13).

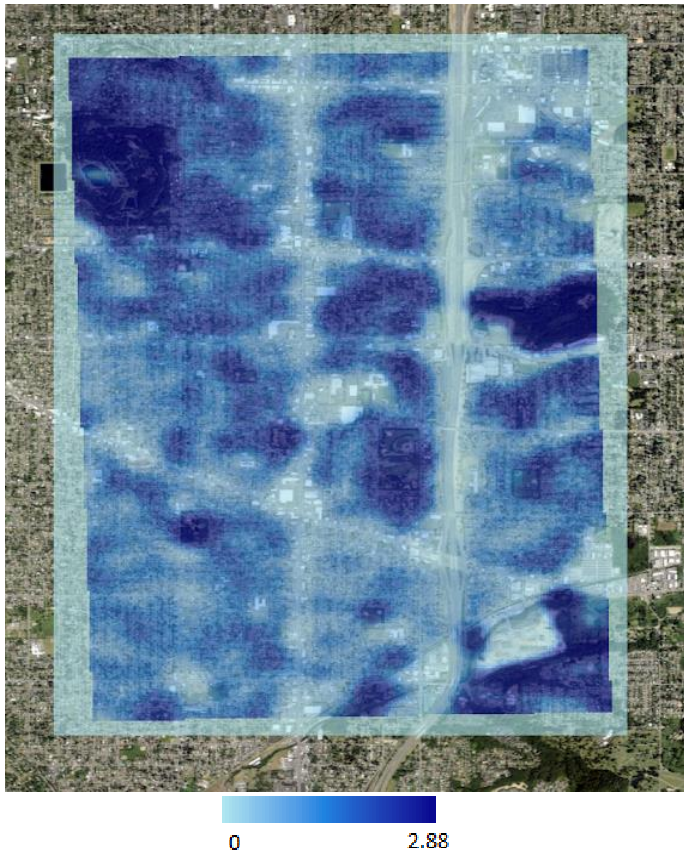


Figure 13: Modeled NO_2 reductions (ppb) over Jade District area.

Standard functions describing the health effects of NO_2 are provided in BenMAP, and rates of baseline incidence are provided in the software by the World Health Organization (WHO). To calculate the exposed population levels, the software application PopGrid aggregates Census population data by race-ethnic group to each cell. PopGrid is a program available free from the web that automatically outputs population data in the appropriate format for BenMAP. As the formatting is highly particular, constructing inputs to BenMAP by hand is tedious but possible given appropriate data through alternative sources such as dasymetric mapping. These inputs support the estimation of the change in incidence by health effect and uses valuation functions from studies of willingness-to-pay to determine the economic value (Table 2).

Table 2: Reductions in incidence and valuation by health effect due to reduced NO_2

Health Effect	Incidence Reduction	Valuation in 2040 ($)
Acute Respiratory Symptoms	1.740	88.65
Asthma Exacerbation	22.860	3639.07
Emergency Room Visits	0.002	10.88
Hospital Admissions, Respiratory	0.015	132.90

Incidence reduction is greatest for asthma exacerbation, with an estimated reduction of 22.86 cases across the population and estimated value of $3,639 in 2040 dollars. We estimate that the value is highly under-estimated due to the quantification, which remains one of the only models to quantifying the health benefits. The incidence and economic value are estimated solely for the year 2040, when the planted trees would reach the modeled 35% maturity, and does not represent the additional benefit provided as the trees grow from initial planting. An additional function of BenMAP is to incorporate the accumulated effects of tree benefits over time, i.e. as the tree grows, the cumulative benefit it provides to a population as it ages. Due to time constraints, this function was not explored but could provide a higher prediction of health incidence reduction and economic value of targeted new plantings. The effects of other harmful pollutants, such as ozone, particulate matter, and sulfur dioxide, can also be examined by BenMAP and may be subject for future analyses.

It is unclear how applying this tool at the micro-scale, rather than a larger, regional scale, affects the magnitude of the outputs – we know of no other analysis that has applied BenMap to this scale of analysis, and future studies will need to evaluation the strengths and limitations of such micro-scale applications. This analysis focused primarily on a single-family residential area, which is less dense in population than other types of land use and hence may indicate lower levels of health incidence and valuation than a more densely populated area. Further research at the district scale would help to address this potential discrepancy.

6. Conclusions

The results of this project builds off several earlier studies, and provides a framework for examining the local-area effects of tree planting efforts. We used existing tree planting data and future growth scenarios to assess changes in district and city-block temperatures and NO_2. The results suggest that current tree plantings make a difference, though those improvements in environmental quality are best reaped into the future. Strategic tree plantings were shown to reduce ambient temperatures by a city-block average of 1.3C. Across the district, the overall reduction in temperatures in future years averages near 2.8C with a 10% increase in temperatures. In terms of NO_2, the tree plantings had a difference of 2.9 ppb, roughly a 13% reduction of the highest NO_2 levels found across Portland.

This initial assessment will enable us to develop a framework to test the ability of existing data and techniques to improve the quality of urban atmospheres. We envision expanding these initial findings to include representative atmospheric characterizations across all seasons, across multiple cities, and the development of engagement systems that allow communities to evaluate the effectiveness of alternative mitigation and adaptation scenarios., The ultimate development of empirically-based scenario assessment tool will facilitate more comprehensive analyses of the multiple ways in which any prospective health strategies may affect the urban climate system, and any urban form and land use plans and policies may affect localized air quality.

7. References

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Appendix D: Modeling Water Quality Benefits of Jade District Greening

WILLAMETTE PARTNERSHIP

Modeling Water Quality Benefits of Jade District Greening

September 2018

Willamette Partnership

1 Introduction

We know that more greenspace, tree canopy, and access to natural features improves environmental quality and human health. Greening projects are known to improve water quality of runoff from parking lots, roads, and other impermeable surfaces by capturing and filtering sediment, nutrients, and heavy metals. These greening efforts also reduce the peak and overall quantity of stormwater runoff into local water ways.

Partners and community members in Portland's Jade District are actively working to improve greenspace and to enhance these benefits in the community. The Jade District encompasses Oregon Census Tracts 83.01, 16.02, and 6.01 (about 2.06 square miles and 14,000 people) and is one of Oregon's most ethnically and linguistically diverse communities. These greening efforts include residential and commercial street tree planting, small greenspaces attached to businesses, and green infrastructure tied into transportation and safety improvements.

To help community leaders better evaluate, track, and communicate the benefits of greening projects in their communities, we quantified the water quality benefits from tree plantings in the Jade District. Our methodology can be replicated by community leaders, in the Jade District and beyond, to measure the impact of tree planting on stormwater quality.

2 Background

Urban areas can contribute to water quality issues when stormwater from precipitation events runs off or is directed from these areas to drainages and streams. The stormwater runoff from urban areas can mobilize pollutants from yards and open space areas (e.g., sediment, fertilizer, pathogens and bacteria from pet waste, and pesticides) as well as pavement and other impervious surfaces (e.g., chemical and petroleum product spills and deposition of air pollutants from mobile sources, such as motor vehicles). These pollutants can make their way into the environment and water bodies where they can affect fish and wildlife and cause detrimental human health affects (e.g., skin irritation, sickness, and contaminated drinking water). They can also result in negative secondary affects that can further exacerbate water quality issues, such as algal blooms that can reduce dissolved oxygen needed for aquatic species or produce toxins dangerous to people, fish, and other animals (EPA, 2018a).

In this study we model the water quality benefits from tree planting in the Jade District by looking at the pollutant load reductions for total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorous (TP), total nitrogen (TN), copper (Cu), lead (Pb), and zinc (Zn). Sediment (TSS) can carry bacteria and pathogens that cause disease in people, fish, and animals. The pollutant indicators of BOD and COD determine how much oxygen is available for aquatic species and can result in anoxic conditions where there is not enough oxygen in water bodies for these aquatic species to survive. Nutrients such as TN and TP can cause algal blooms and eutrophication that each can have secondary negative water quality effects, including the release of algal toxins and reductions in oxygen within these water bodies. Metals such as Cu, Pb, and Zn are toxic to both people and animals and can lead to a variety of adverse health effects including neurological diseases and disorders (Gaffield et al., 2003).

Planting trees can improve water quality and reduce the pollutants carried into the environment and our water bodies by diminishing the amount of stormwater runoff that occurs during precipitation events. Trees are able to reduce the amount of stormwater runoff through interception that occurs when precipitation is caught in the tree canopy and evaporates before reaching the ground. The tree canopy also serves to reduce the amount of force or energy that precipitation has when it hits the ground, resulting in less mobilization of sediment and other pollutants deposited on the ground. Tree roots are able to increase the precipitation that can infiltrate into the soil and that can be held there, instead of running off and carrying pollutants into receiving water bodies. This water is then taken up by the tree where it is used within the tree or undergoes transpiration where it is released by the tree during photosynthesis and evaporated into the atmosphere (EPA, 2018b). With a reduction in stormwater runoff as a result of more trees, fewer pollutants are mobilized and deposited into the environment and receiving water bodies.

3 METHODOLOGY

3.1 WATER QUALITY MODEL SELECTION

Willamette Partnership conducted a review of water quality models that could meet the objectives of estimating the water quality benefits of the Jade District greening projects and demonstrating a methodology that could be easily replicated by community leaders to evaluate, track, and communicate the water quality benefits of their greening projects. Over 50 water quality models were reviewed based on whether their outputs include numeric pollutant load reductions, their ability to evaluate tree planting water quality benefits specifically, accuracy at the geographic scale of the Jade District greening projects, complexity and usability, relative availability of information needed as inputs to the model, and accessibility to community leaders.

The water quality models that meet the general project objectives of usability and accessibility could be characterized by three general categories:

1. Models that provide pollutant load reductions from natural infrastructure as an output, but that do not specifically model the effects of trees (e.g., SELECT Model from the Water Research Foundation and the Storm Water Management Model [SWMM] from the EPA).
2. Models that can specifically account for trees, but that don't provide pollutant load reductions as a direct output (e.g., National Stormwater calculator [SWC] by the EPA and the Center for Neighborhood Technology Green Values National Stormwater Management Calculator).
3. Models that can both model trees specifically and that directly calculate pollutant load reductions (e.g., i-Tree Hydro).

The review found a number of models that did not meet all of the desired criteria for the Jade District greening projects, with only one model (i-Tree Hydro Version 5) fully meeting all of the objectives for the project. Based on this evaluation i-Tree Hydro was selected as the water quality model for this project. I-Tree Hydro is free and downloadable from the internet, allows a comparative analysis of different tree canopy cover (i.e., tree planting) scenarios, provides a variety of pollutant load reductions as a direct output, and is simple to use for non-experts (the model includes pre-loaded default values and input datasets) yet accurate and defensible for planning-level comparative analysis.

3.2 Assumptions and Inputs

The assumptions and inputs for the water quality modeling of the Jade District greening projects using i-Tree Hydro were intended to align with the assumptions and data being used for the modeling of air quality and heat island benefits (see Appendix C). Similar inputs from the air quality modeling that were used in the water quality modeling include tree canopy sizes at maturity; Jade District geographic boundary; future tree planting scenarios; and tree planting amounts, species, and locations. As a result, all of the multiple benefits provided by the Jade District greening projects, such as water quality, air quality, and heat island benefits, could all be considered together in a cohesive manner.

In addition to being consistent with the information used in the air quality modeling exercise, modeling the water quality benefits of the Jade District greening projects maximized the amount of pre-loaded data inputs in i-Tree Hydro that were applicable to the project. This included pre-loaded weather and precipitation data from the Portland International Airport weather station, U.S. Geological Survey (USGS) historical stream gauge data for Johnson Creek, and topography of the City of Portland. Each of these data inputs were accurately representative of the Jade District and demonstrated the usability of the model that could be replicated by community leaders for greening projects in similar or different locations. Furthermore, using the pre-loaded datasets allows the model to be auto-calibrated, reducing the number of steps and the complexity of using the model for community leaders.

Some project-specific inputs into the water quality model were required that were not pre-loaded/default values in i-Tree Hydro. In these cases, the information was determined from related, reputable, and easy to use/access sources. For example, to determine the percentage of existing and future tree canopy in the Jade District that is above pervious or impervious surfaces, i-Tree Canopy (a companion online software to i-Tree Hydro used to statistically determine land cover types using aerial imagery) was used. Similarly, to determine the predominant soil type in the Jade District, the U.S. Department of Agriculture Natural Resources Conservation Service's (NRCS) Web Soil Survey online tool was used. The Portland Parks and Recreation's Street Tree Inventory was used as the baseline for tree cover in the Jade District, prior to the greening activities. The inventory was last conducted in the Jade District in 2014. Other information, such as the estimate of new trees planted over impervious or pervious surfaces was derived from tree planting information provided by Jade District greening partner organizations. A complete set of calculation inputs and assumptions can be found in Appendix A.

To determine the added water quality benefits of the current Jade District greening projects and the potential for added future water quality benefits of continued greening efforts, the following scenarios were run in i-Tree Hydro:

- 0.4% tree canopy increase from trees at 35% maturity already planted as part of the Jade District greening projects through 2018, compared to the 2014 Street Tree Inventory.
- 5% tree canopy increase in the Jade District.
- 10% tree canopy increase in the Jade District.
- 15% tree canopy increase in the Jade District.

To estimate the increase in tree canopy from Jade District tree planting from 2014 through 2018, the spread of each tree species planted at 35% maturity and at full maturity was calculated to determine the increase in tree canopy area. The existing tree canopy area in the Jade District was estimated from i-Tree Canopy, which uses a statistical sampling method and aerial photography to determine the percentage of different land cover types. This method was used with a number of samples sufficient to result in a less than 3% margin of error for each land cover type. The resulting estimate for the existing percentage of tree canopy land cover was then multiplied by the Jade District boundary area to estimate the existing tree canopy cover area. The percentage increase in tree canopy was then determined based on the existing tree canopy area in the Jade District and the increase in tree canopy area from tree plantings in the Jade District from 2014 through 2018 at maturity.

The increase in tree canopy scenarios of 5%, 10%, and 15% are meant to inform the type of tree canopy cover that could exist in Jade District in the future. Based on the i-Tree Canopy results showing an existing tree canopy cover of approximately 24% (with approximately +/- 4% standard error), the 5% and 10% increase in tree canopy scenarios could achieve the City's goal of 33.3% tree canopy cover by 2025 (City of Portland Parks & Recreation, 2004). The 15% increase in tree canopy scenario is intended to show the potential benefits of further tree planting in the Jade District that begins to utilize the maximum potential tree canopy available in this area. An estimate of the maximum tree canopy potential can be approximated by the Street Tree Inventory Reports for the three neighborhoods designated by the Portland Parks & Recreation Department that overlap with the Jade District. The most conservative of these street tree inventory reports, the Lents Neighborhood Street Tree Inventory Report, estimated a maximum tree canopy potential increase of 27% (City of Portland Parks & Recreation, 2016).

4 Results

The water quality model (i.e., i-Tree Hydro) was run for each of the future scenarios using historical weather, precipitation, and stream gauge data for 7 years (2005 to 2012) and then averaged to determine an annual average pollutant load reduction estimated to occur in Jade District runoff/stormwater as a result of the Jade District greening projects. Pollutant load reductions from Jade District runoff/stormwater for each of the future scenarios were calculated for TSS, BOD, COD, TP, TN, Cu, Pb, and Zn. The results for each scenario are presented in Tables 1 through 4.

Table 1: Jade District Greening Projects (2014-2018) Water Quality Benefits		
Pollutant [a]	Annual Average Pollutant Load Reduction (kg/hr) [b]	Percent Pollutant Load Reduction [c]
TSS	510.5	0.05%
BOD	91.6	0.05%
COD	343.2	0.05%
TP	2.0	0.05%
TN	11.3	0.05%
Cu	0.09	0.05%
Pb	0.4	0.05%
Zn	1.1	0.05%

Note: [a] Total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorous (TP), total nitrogen (TN), copper (Cu), lead (Pb), and zinc (Zn).
[b] Annual average pollutant loads expressed in kg of pollutant per hour (kg/hr) based on 7 years (2005-2012) of historic weather, precipitation, and stream gauge data for the Johnson Creek watershed.
[c] Percent pollutant load reduction based on comparison to pollutant loads before Jade District greening projects.

Table 2: Water Quality Benefits of 5% Tree Canopy Increase in the Jade District		
Pollutant [a]	Annual Average Pollutant Load Reduction (kg/hr) [b]	Percent Pollutant Load Reduction [c]
TSS	6,372.2	0.63%
BOD	1,145.6	0.63%
COD	4,290.7	0.63%
TP	25.6	0.63%
TN	140.6	0.63%
Cu	1.10	0.63%
Pb	5.5	0.63%
Zn	13.2	0.63%

Note: [a] Total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorous (TP), total nitrogen (TN), copper (Cu), lead (Pb), and zinc (Zn).
[b] Annual average pollutant loads expressed in kg of pollutant per hour (kg/hr) based on 7 years (2005-2012) of historic weather, precipitation, and stream gauge data for the Johnson Creek watershed.
[c] Percent pollutant load reduction based on comparison to pollutant loads before Jade District greening projects.

Table 3: Water Quality Benefits of 10% Tree Canopy Increase in the Jade District		
Pollutant [a]	Annual Average Pollutant Load Reduction (kg/hr) [b]	Percent Pollutant Load Reduction [c]
TSS	12,740.2	1.26%
BOD	2,291.3	1.26%
COD	8,580.5	1.26%
TP	51.2	1.26%
TN	281.1	1.26%
Cu	2.19	1.26%
Pb	11.0	1.26%
Zn	26.3	1.26%

Note: [a] Total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorous (TP), total nitrogen (TN), copper (Cu), lead (Pb), and zinc (Zn).
[b] Annual average pollutant loads expressed in kg of pollutant per hour (kg/hr) based on 7 years (2005-2012) of historic weather, precipitation, and stream gauge data for the Johnson Creek watershed.
[c] Percent pollutant load reduction based on comparison to pollutant loads before Jade District greening projects.

Table 4: Water Quality Benefits of 15% Tree Canopy Increase in the Jade District		
Pollutant [a]	Annual Average Pollutant Load Reduction (kg/hr) [b]	Percent Pollutant Load Reduction [c]
TSS	18,917.0	1.86%
BOD	3,402.3	1.86%
COD	12,740.4	1.86%
TP	76.0	1.86%
TN	417.4	1.86%
Cu	3.26	1.86%
Pb	16.3	1.86%
Zn	39.1	1.86%

Note: [a] Total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorous (TP), total nitrogen (TN), copper (Cu), lead (Pb), and zinc (Zn).
[b] Annual average pollutant loads expressed in kg of pollutant per hour (kg/hr) based on 7 years (2005-2012) of historic weather, precipitation, and stream gauge data for the Johnson Creek watershed.
[c] Percent pollutant load reduction based on comparison to pollutant loads before Jade District greening projects.

5 DISCUSSION

The current Jade District greening efforts provide a variety of benefits to the community including improved air quality, reduced heat island effect, and increased aesthetic appeal. Willamette Partnership has quantified the added water quality benefits from the completed Jade District greening projects and analyzed the potential water quality benefits if further tree planting would occur. The modeling demonstrates that there is a modest reduction in pollutants and the amount of stormwater as a result of the tree planting that has occurred in the Jade District. Based on the scale of this project and the level of detail used in modeling these water quality benefits, the proportion of pollutant load reduction for each of the pollutants was similar because they were predominantly determined by the same amount of stormwater runoff that was reduced as a result of the tree planting. This modest water quality improvements from the completed Jade District greening projects are primarily a result of the limited amount of trees planted during these projects. As the amount of trees planted in the Jade District increases, the reduction in pollutants and volume of stormwater runoff also increases. If enough trees were planted in the Jade District to meet the City's target of having 33.3% tree canopy by 2025, the Jade District would see approximately a 1% improvement in both water quality pollutant and stormwater quantity reduction. The results of larger amounts of tree canopy in the Jade District beyond the City's goal indicate that these benefits will continue to accrue and could account for a reduction in pollutant loadings and stormwater quantity by multiple percentage points.

Furthermore, although the annual average pollutant load reduction from the completed Jade District greening projects only represent a small reduction in the total pollutant load from the Jade District, the trees provide multiple other benefits. The City of Portland's Street Tree Inventory (City of Portland Parks & Recreation, 2017) valued these multiple benefits from street trees in the City and found that stormwater benefits (e.g., reduction in pollutants transferred to water bodies and lower costs of stormwater treatment) of a single street tree is worth over $20. When accounting for the other multiple benefits (e.g., air quality, heat reduction, and aesthetics) of street trees the total tree value for planting a single street tree was found to be just over $131.

The process, methodology, and tools used to evaluate the water quality benefits from the Jade District greening projects is a potential model for use by local community leaders. The low complexity, data availability, and pre-loaded information make i-Tree Hydro and the quantification method used in this report easily accessible to community leaders. This process will help these community leaders evaluate, track, and communicate one of the multiple benefits of their greening projects.

6 RECOMMENDATIONS

The methodology for modeling the potential water quality benefits from tree planting in the Jade District was intentionally chosen to be reproducible by other community leaders for their efforts to evaluate, track, and communicate the benefits of greening projects. Although i-Tree Hydro can be used to more accurately model water quality and stormwater benefits for particular receiving streams (e.g., by using site-specific digital elevation models and user-defined stream gauge and weather data), utilizing the pre-loaded dataset and default inputs can provide a low complexity method for quantifying general water quality benefits from tree planting. Modeling the water quality benefits of the Jade District greening projects revealed a few key lessons were learned for community leaders to replicate this method for their own greening projects:

- **Check to see how well represented your location is in i-Tree Hydro:** How accurately i-Tree Hydro can model your location and project depends on how representative these data are to your location. It is important to ensure that i-Tree Hydro can specifically list your location and has stream gauge, weather station, and topographic data that is near to or encompasses your project site.

- **Setting a tree canopy goal is the easiest way to model water quality benefits in i-Tree Hydro:** The most difficult input parameter to determine using the low complexity methodology described in this case study is the future percentage of tree canopy cover and what land cover types the increase in tree canopy cover will replace. This is due to the fact that often tree planting projects are described in the number of trees planted, which needs to be translated into tree canopy spread. Instead of searching for mature tree canopy spread areas for each tree species and doing manual calculations to determine this input parameter, it is easier for community leaders to have a goal in mind of the amount of tree canopy increase they would want to achieve in their project area. Identifying the goals within your local jurisdiction or of similar areas to your project is an easy way to reduce the complexity associated with modeling water quality benefits from tree planting using i-Tree Hydro.
- **Use reputable sources of data and information if you are going to change default values in i-Tree Hydro:** The more site-specific information you can use as your inputs to i-Tree Hydro the more accurate your modeling will be. However, some inputs are difficult to determine without more advanced knowledge of trees, hydrology, and geology. Using reputable data sources such as National Oceanic and Atmospheric Administration (NOAA) and NRCS are good alternatives to using default values or having advanced, site-specific knowledge of the input parameters.
- **Be able to determine trees covering mostly impervious or pervious surfaces in your data:** When collecting data on tree plantings, it is important to include if the tree will be covering mostly impervious or pervious surfaces for the purpose of modeling the water quality benefits in i-Tree Hydro. Different land cover types result in different pollutants and stormwater quantities so collecting this data upfront during tree surveys or planting plans is a critical piece of information to be able to accurately evaluate the water quality benefits of tree planting projects.

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APPENDIX A: I-TREE HYDRO DETAILED METHODOLOGY

The methodology for calculating water quality impacts in i-Tree Hydro for this project focused on utilizing a simple approach that could be replicated by community leaders with varying levels of technical knowledge to evaluate and communicate the water quality benefits of community greening projects. To increase the replicability of this water quality modeling, the methodology included utilizing the pre-loaded datasets, default values, as well as frequently used and reliable input data sources to the extent possible. The following provides a detailed explanation of model inputs, data sources, and example images from the i-Tree Hydro software interface (additional model information and free download available at: https://www.itreetools.org/hydro/).

Step 1: Project Area Information

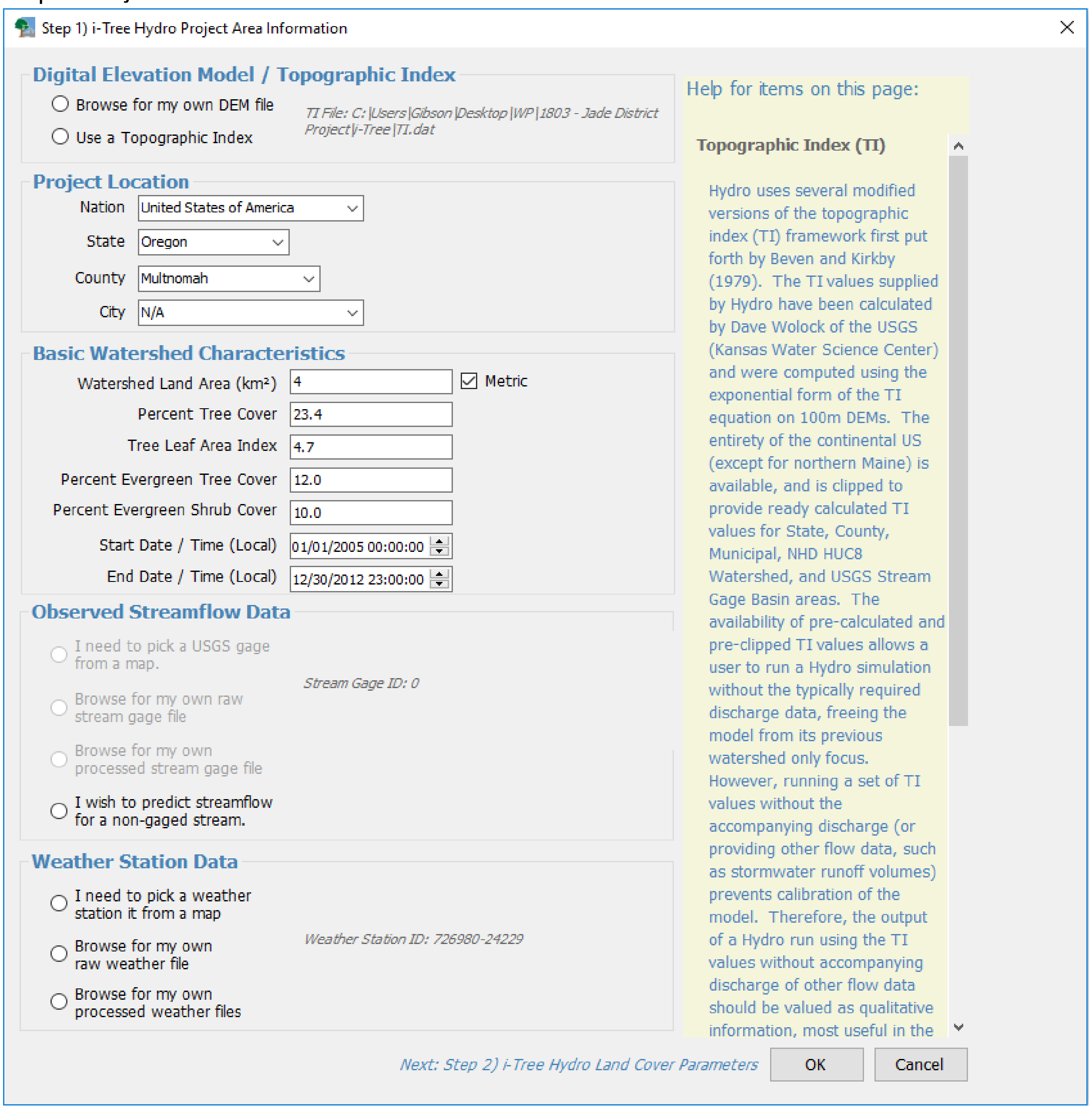


Figure A1. i-Tree Hydro Project Area Information Input Screen

- A pre-loaded topographic index file for Multnomah County (smallest area that encompasses the project boundary) was used for the land surface elevation input data (see Figure A1).
- The most specific, pre-loaded project location was also selected as Multnomah County.
- The Jade District boundary was defined by the project team and partners and the area was measured in Google Earth for the watershed land area input (see Figure A2). This was done to bound the modeling area to just the size of the Jade District.

Figure A2. Aerial Photograph of Jade District Boundary

- The percent tree cover input was determined using i-Tree Canopy (available at https://canopy.itreetools.org), a companion program to i-Tree Hydro, that allows the user to define a project boundary and uses a random sampling of aerial photography (with the land cover type of each sample determined manually by the user) to statistically determine the proportion of each land cover type in the project area. For this project, the project area was defined manually in i-Tree Canopy using the polygon tool (see Figure A3).

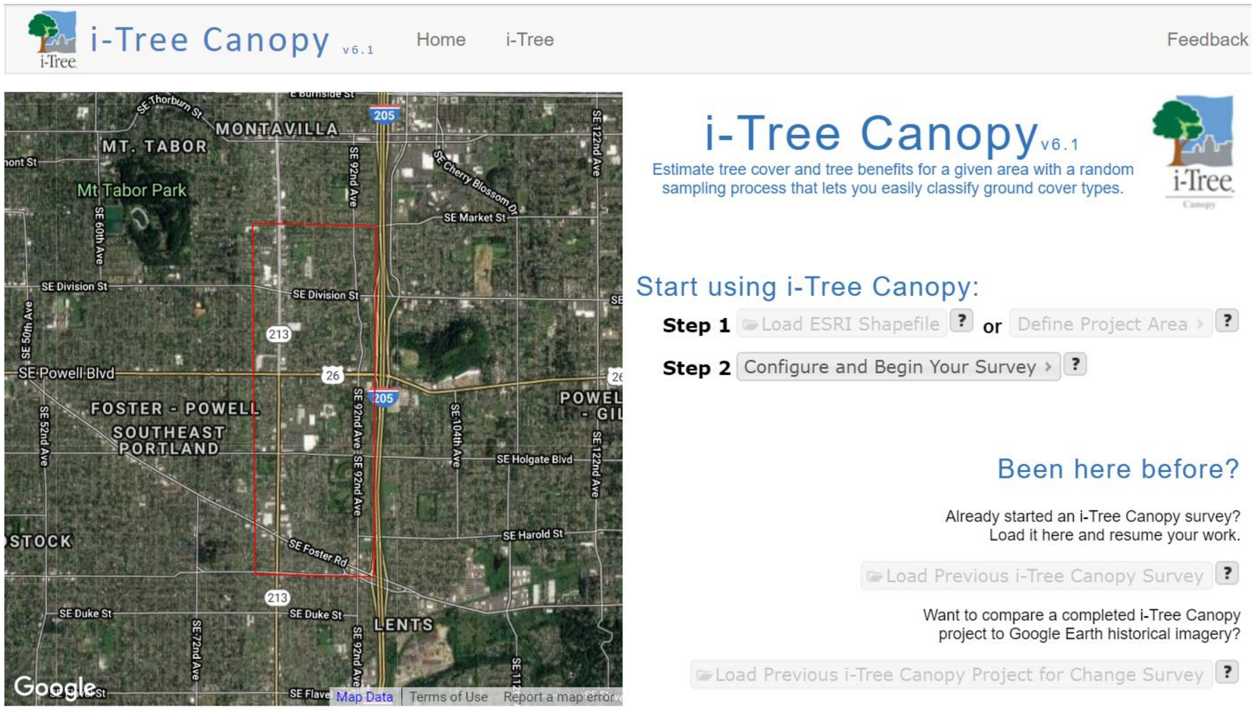


Figure A3. i-Tree Canopy Define Project Area Screen

- Seven possible land cover types were established by the user for the sampling processes, which included tree canopy over impervious surfaces, tree canopy over pervious surfaces, impervious surfaces, herbaceous, shrub, water, and bare soil. It is important to note that these are the land cover types that must be input into i-Tree Hydro so it is essential that the user define these seven land cover types when sampling in i-Tree Canopy (see Figure A4).

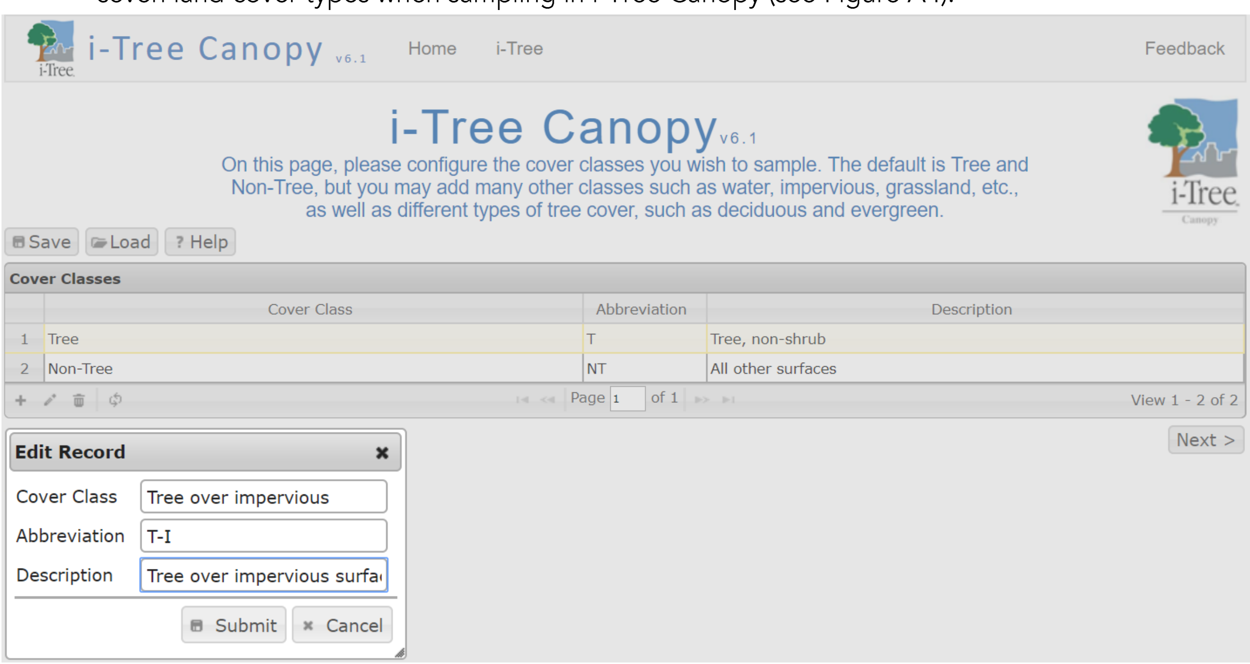


Figure A4. i-Tree Canopy Defining Land Cover Types Screen

- After defining the seven land cover types i-Tree Canopy will randomly select points in the project boundary and the user defines what land cover type exists at the point based on aerial photography. This processes was repeated for the Jade District project until enough samples were collected to bring the standard error for each land cover type to below plus/minus 3% (see Figure A5). The results were then input as the percent tree cover parameter in the i-Tree Hydro project area information screen.

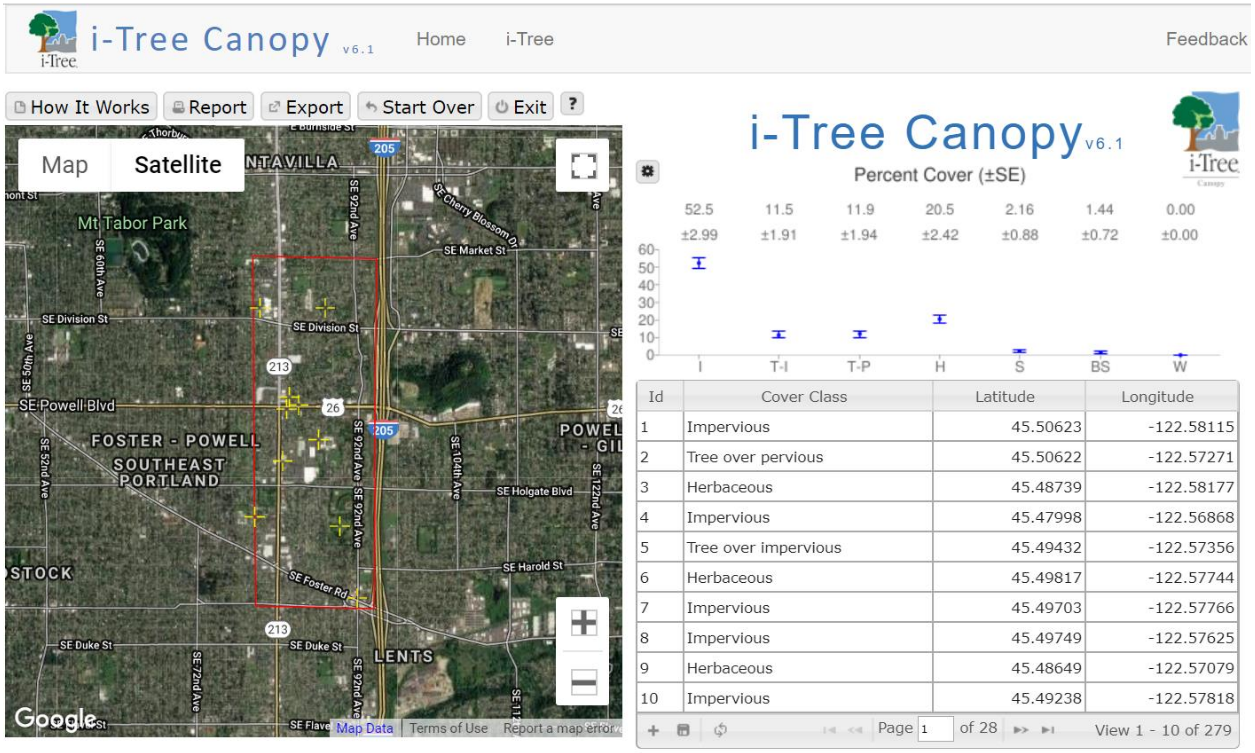


Figure A5. i-Tree Canopy Sampling Screen

- The default value for tree leaf area index was used as it was a conservative estimate of the typical variety of tree species existing in the Jade District (see Thomas and Winner, 2000 for estimates of typical Douglas-fir forests for comparison to default leaf area index value).
- The percent evergreen trees value was determined based on public information from the City of Portland on the typical composition of street trees (Portland Parks & Recreation and Portland State University, 2014). This amount is considered conservative as it is less than the evergreen tree composition of park trees and therefore, likely under-represents the evergreen tree proportion (evergreen trees typically provide more annual water quality benefits because they retain their foliage year-round).
- The default value for evergreen shrub proportion was selected.
- The start and end times were selected to include the entire pre-loaded weather datasets in i-Tree Hydro.
- The streamflow data was input as manually predicted because this project was focused on a specific project area and not the water quality health of a particular stream (the user defined input parameters are given on a later screen).
- The closest pre-loaded weather station (Portland International Airport) was selected to provide precipitation and weather data that would be used to calculate pollutant loads from stormwater runoff.

Step 2: Land Cover Parameters

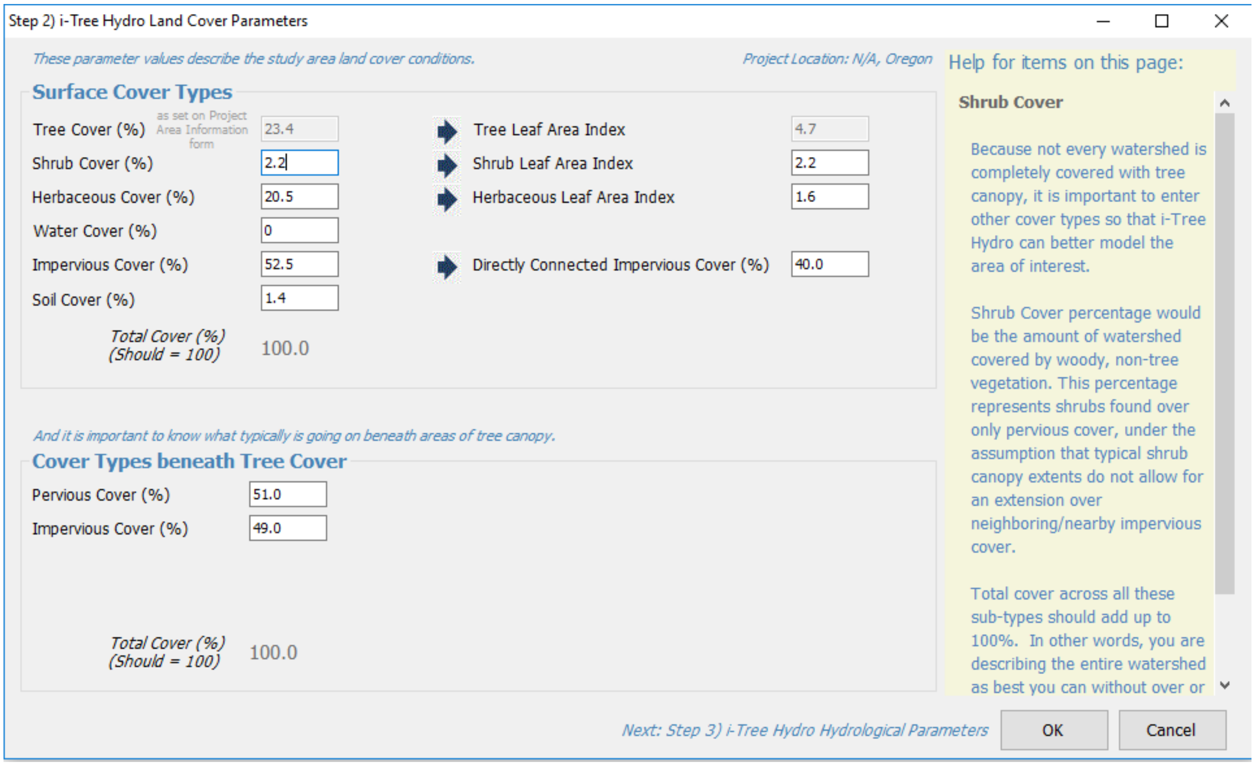


Figure A6. i-Tree Hydro Land Cover Parameters Screen

- The existing land cover proportions determined in i-Tree Canopy were input into the "surface cover types" category (see Figure A6).
- Default values for shrub and herbaceous leaf area indices were selected.
- The default value for directly connected impervious cover was used.
- The proportion of pervious and impervious surfaces beneath tree canopy cover was calculated from the samples in i-Tree Canopy and input into the model.

Step 3: Hydrological Parameters

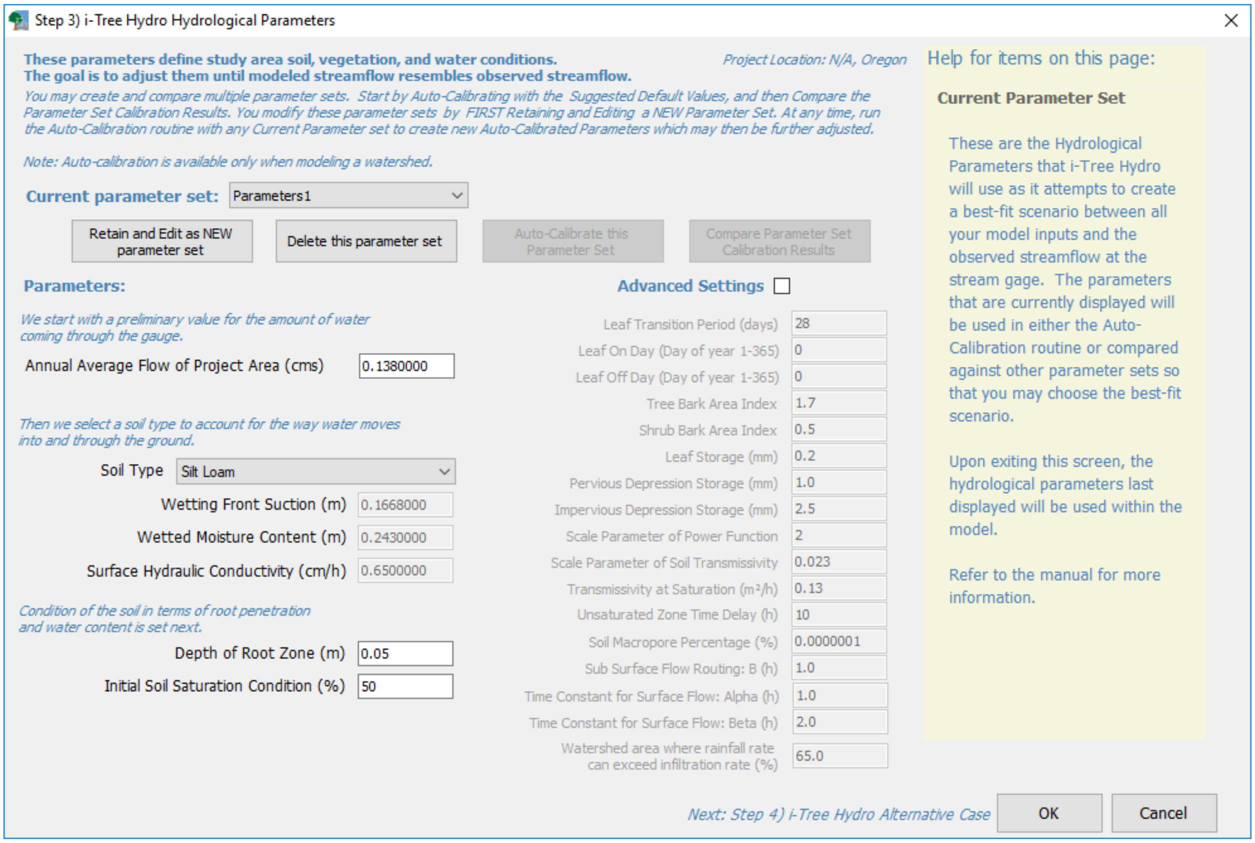


Figure A7. i-Tree Hydro Hydrological Parameters Screen

- The annual average flow of the project area in cubic meters per second (cms) was calculated in excel by multiplying the annual rainfall depth based on 30 years of historical rainfall data for Portland, Oregon (NOAA National Weather Service Forecast Office, 2017) by the area of the Jade District (see Figure A7 and Figure A8).

Calculations				**Conversions**	
Average Annual Precipitation	42.85	inches/year		39.3701	inches/meter
	1.09	meters/year		31540000	seconds/year
	3.45082E-08	meters/second			
Project Area	987	acres		4046.86	m^2/acre
	3,994,251	m^2			
Annual Average Flow	0.13783	m^3/second			
*assumes 100% runoff					
*annual average precipitation based on NOAA data https://www.wrh.noaa.gov/pqr/pdxclimate/pg90.pdf.					

Figure A8. Excel Calculations for Annual Average Flow of Project Area

- The predominant soil type was determined using the online Web Soil Survey tool (USDA NRCS, 2018).

- Default values were selected for the remaining hydrological parameters, including root zone depth and initial soil saturation condition.

Step 4: Define Alternative Case

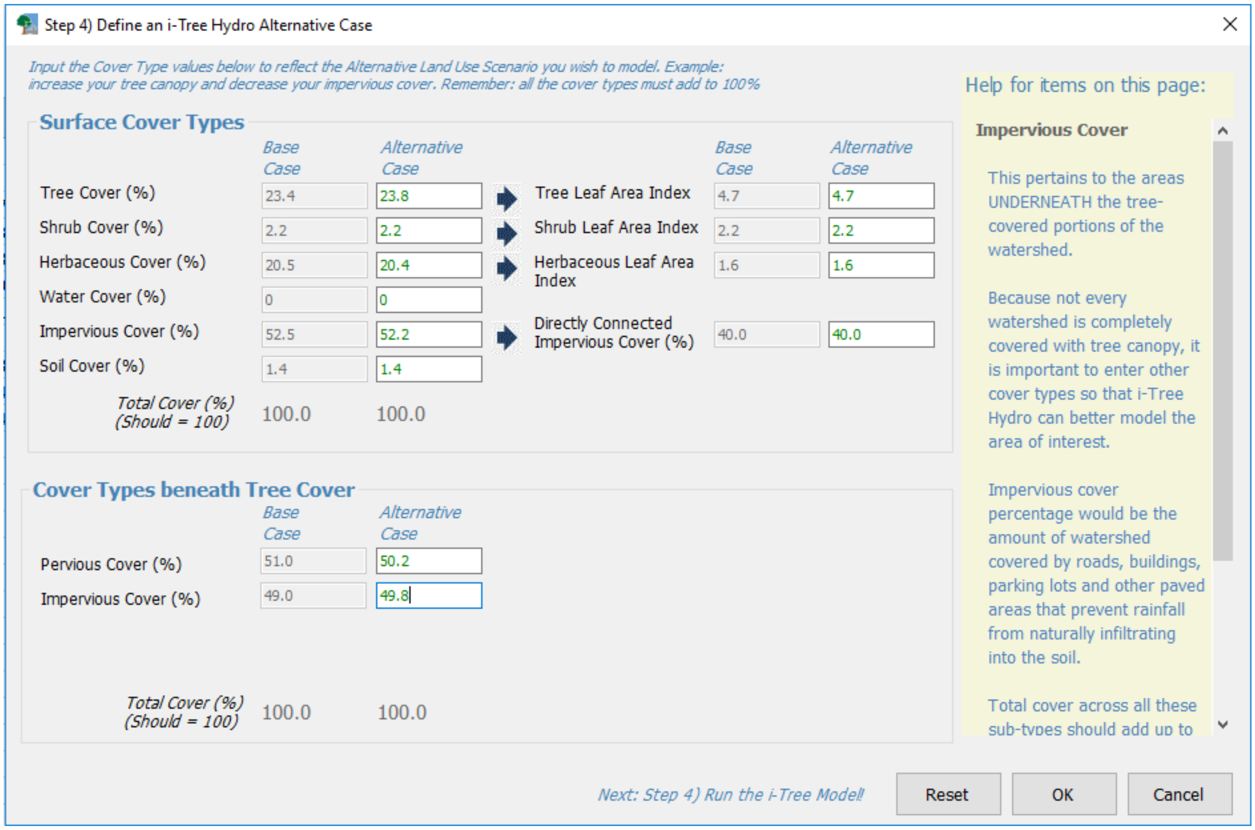


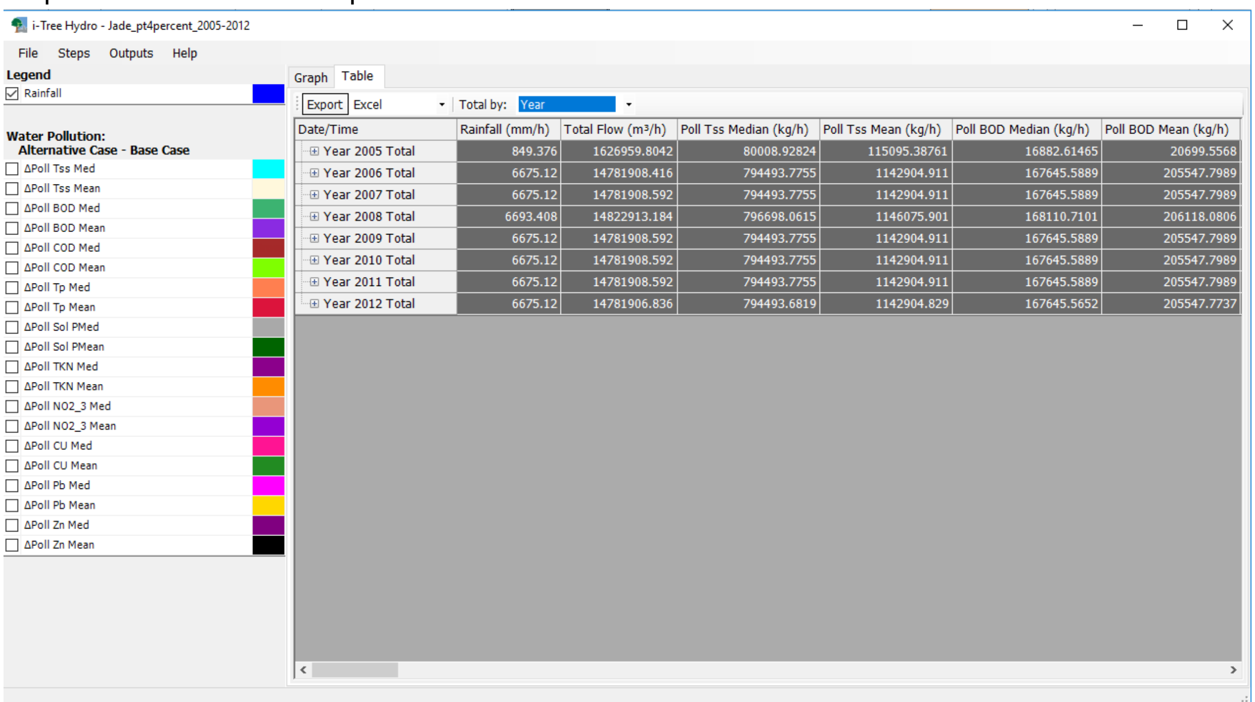
Figure A9. i-Tree Hydro Define Alternative Case Screen

- To determine the increase in tree canopy percentage, the full maturity leaf spread of the tree species planted as part of the Jade District greening projects (through 2018) were determined. It was conservatively assumed that these trees would only be at 35% maturity for this scenario. This conservative assumption accounts for the rate of growth of the tree species planted and slowed growth or mortality of the planted trees and was determined after consulting a professional arborist. It should be noted that at full maturity the planted trees in the Jade District would exceed this canopy cover estimate and provide greater water quality benefits. After determining the 35% maturity canopy spread area for each tree planted, the percent increase in tree canopy for the Jade District was determined using the total area of the Jade District boundary and the percent tree canopy cover previously calculated in i-Tree Canopy to calculate the existing tree canopy area. The added tree canopy area from the tree plantings was then compared to the existing tree canopy area to determine the percent in tree canopy increase as a result of the Jade District greening projects.
- To balance the total land cover to 100%, the location of the trees planted as part of the Jade District greening projects were used to determine what type of land cover they would replace. Trees planted on the streets were assumed to replace impervious surfaces and trees planted in residential yards were assumed to replace herbaceous surfaces. These two land cover inputs were reduced by the proportion of new trees planted in each of those areas (75% planted on

streets/over impervious and 25% planted in residential yards/over pervious) to balance the total land cover to 100%.

- To determine the new (alternative case) impervious and pervious proportion below the new tree canopy cover the location of the planted trees (on the street or in a residential yard) was used to calculate the proportion of new trees planted over impervious surfaces (assumed to be those planted by streets) and over pervious surfaces (assumed to be those planted in residential yards). The tree canopy area for the newly planted trees for both trees over impervious surfaces and trees over pervious surfaces was then added to the existing tree canopy area (estimated in the process described above) and existing distribution of trees over impervious and pervious surfaces (estimated from i-Tree Canopy results) to determine the new distribution of total tree canopy (including new tree plantings) over impervious and pervious surfaces for the Jade District.

Step 5: Run Model and Outputs



Date/Time	Rainfall (mm/h)	Total Flow (m³/h)	Poll Tss Median (kg/h)	Poll Tss Mean (kg/h)	Poll BOD Median (kg/h)	Poll BOD Mean (kg/h)
Year 2005 Total	849.376	1626959.8042	80008.92824	115095.38761	16882.61465	20699.5568
Year 2006 Total	6675.12	14781908.416	794493.7755	1142904.911	167645.5889	205547.7989
Year 2007 Total	6675.12	14781908.592	794493.7755	1142904.911	167645.5889	205547.7989
Year 2008 Total	6693.408	14822913.184	796698.0615	1146075.901	168110.7101	206118.0806
Year 2009 Total	6675.12	14781908.592	794493.7755	1142904.911	167645.5889	205547.7989
Year 2010 Total	6675.12	14781908.592	794493.7755	1142904.911	167645.5889	205547.7989
Year 2011 Total	6675.12	14781908.592	794493.7755	1142904.911	167645.5889	205547.7989
Year 2012 Total	6675.12	14781906.836	794493.6819	1142904.829	167645.5652	205547.7737

Figure A10. i-Tree Hydro Water Pollution: Alternative Case – Base Case Table Screen

- The i-Tree Hydro model was run using the previously described input parameters and the output for Water Pollution: Alternative Case – Base Case was totaled by year in the table tab (see Figure A10).
- The average for all years was calculated after exporting the results to excel.
- The mean change in pollutant load for TSS, BOD, COD, TP, TN, Zn, Cu, and Pb for the average of the seven years of data was then recorded and compared to the mean pollutant load (average of the seven years of data) for the Base Case (existing conditions before tree plantings) to determine the percent reduction in pollutant load for each pollutant. By averaging the seven years of historical data the results are descriptive of the pollutant loadings expected for type of precipitation experienced in the Jade District, while providing a robust estimate of the annual

average for these pollutant loadings that is less influenced by a single year of high or low precipitation (or high or low proportion of large or small precipitation events).

Willamette Partnership is a 501(c)3 nonprofit based in Portland, Oregon. With more than 20 years of experience convening partners and developing market-based conservation solutions, Willamette Partnership continues to help others create incentives for investing in conservation and restoration throughout the West. We believe it is increasingly important to do this work in a way that cares for people — making communities more resilient by solving environmental problems that improve health, social, and economic outcomes.

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4640 SW Macadam Ave., Suite 50, Portland, OR 97239 | (503) 946-8350 | info@willamettepartnership.org